UNCLASSIFIED

Registration No.
29840

-Technical Report-

TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model Verification Report

Frank J. Huston II and Gale L. Zielinski

US Army TARDEC, Warren, MI

UNCLASSIFIED: Distribution Statement A
Approved for Public Release

9 November 2017

U.S. Army Tank Automotive Research, Development, and Engineering Center
Detroit Arsenal
Warren, Michigan 48397-5000

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE *03/07.2014*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
9 Nov 2017	Technical	Jan 2014 – Aug 2017

4. TITLE AND SUBTITLE

TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model Verification Report

5a. CONTRACT NUMBER N/A

5b. GRANT NUMBER N/A

5c. PROGRAM ELEMENT NUMBER N/A

6. AUTHOR(S)

Frank J. Huston II and Gale L. Zielinski

5d. PROJECT NUMBER N/A

5e. TASK NUMBER N/A

5f. WORK UNIT NUMBER N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

RDECOM-TARDEC-ACT
Attn: RDTA-SIE-EA-ADCON-TIC
MS 207
6501 E. 11 Mile Road, Warren, MI 48397-5000

8. PERFORMING ORGANIZATION REPORT NUMBER N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

N/A

10. SPONSOR/MONITOR'S ACRONYM(S) N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S) N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT

UNCLASSIFIED: Distribution Statement A. Approved for Public Release, Unlimited Distribution

13. SUPPLEMENTARY NOTES

N/A

14. ABSTRACT

Easy-to-use Computer-Aided Design (CAD) tools, known as accommodation models, are needed by the ground vehicle designers when developing the interior workspace for the occupant. The TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model described in this verification report is applicable to truck-like ground vehicles and may also be used in workstations that require the crew to interact with vehicle controls and non-driving displays using hands, horizontal directed vision, and adjustable seats. The FHP: Driver CAD model is a parametric model that is intended to provide the composite boundaries representing the body of the defined target design population, including posture prediction. Clearances between the occupant and surrounding interior vehicle surfaces have been added per MIL-STD-1472G. Direct vision zones and ground intercept have been added based on MIL-STD-1472G and SAE Recommended Practice J1050. The intention of verification is to build confidence in the CAD accommodation model. Model verification included ten test scenarios for comparing the FHP: Driver CAD model outputs against predefined requirements and acceptability criteria.

15. SUBJECT TERMS

Fixed Heel Point (FHP), occupant workspace, ensemble, verification, Computer-Aided Design (CAD), accommodation model, ground vehicle design, interior workspace, occupant, fixed heel point, target design population, posture prediction.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Gale L. Zielinski
a. REPORT	b. ABSTRACT	c. THIS PAGE		260	19b. TELEPHONE NUMBER *(include area code)*
UNLIMITED	UNLIMITED	UNLIMITED			(586) 282-5287

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std.

TANK-AUTOMOTIVE RESEARCH
DEVELOPMENT ENGINEERING CENTER
Warren, MI 48397-5000

9 November 2017
Revision 1.0

TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model Verification Report

By

Frank J. Huston II and Gale L. Zielinski

REVISION HISTORY

Revision Number	Revision Date	Description of Change
1.0	9 November 2017	Original

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of the following individuals for their assistance in the creation of this report:

Cheryl A. Burns, Army Research Laboratory Human Research and Engineering Directorate (ARL HRED)

Richard W. Kozycki (ARL HRED)

Matthew P. Reed, PhD, University of Michigan Transportation Research Institute (UMTRI)

1. VERIFICATION REPORT EXECUTIVE SUMMARY

Military ground vehicles are currently designed using requirements from MIL-STD-1472G, the *Department of Defense Design Criteria Standard: Human Engineering*. The MIL-STD, however, is difficult for designers to apply properly because it is often open to interpretation. Easy-to-use Computer-Aided Design (CAD) tools are needed by the ground vehicle community to address this issue. The CAD tools being developed are called accommodation models. Accommodation models are constructed from 3D empirical data for a given seating configuration to provide population workspace boundaries that include the effects of both anthropometry and posture (Zielinski, Huston II, Kozycki, Kouba, & Wodzinski, 2015).

Accommodation models provide an opportunity to apply Human Systems Integration (HSI) much earlier in the acquisition process. The models can be utilized during the Material Solution Analysis Phase prior to Milestone (MS)A and through MSB. Past programs have not actively engaged HSI until MSB or the Engineering Manufacturing and Development (EMD) Phase, resulting in significant design and cost changes.

The TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model described in this verification report is applicable to truck-like ground vehicles where driving is controlled via a conventional accelerator pedal and steering wheel. The model may also be used in workstations that require the crew to interact with vehicle controls and non-driving displays using hands, horizontal directed vision, and adjustable seats. The FHP: Driver CAD model is a parametric model that is intended to provide the composite boundaries representing the body of the defined target design population, including posture prediction. Clearances between the occupant and surrounding interior vehicle surfaces have been added per MIL-STD-1472G. Direct vision zones and ground intercept have been added based on MIL-STD-1472G and SAE Recommended Practice J1050.

The intention of verification is to build confidence in the CAD accommodation model. Model verification included ten test scenarios for comparing the FHP: Driver CAD model outputs against predefined requirements and acceptability criteria. Specifically, when given the same inputs, accommodation model geometry from the CAD model was compared to the outputs of the UMTRI *Soldier Driver Accommodation* (2017) model spreadsheet; and boundary manikin hip and eye locations were compared to the outputs of the *Seated Soldier Posture Prediction* (2014) spreadsheet. Because no other models for comparison exist, Subject Matter Experts (SMEs) were used to determine that CAD model outputs for occupant clearances matched the agreed upon interpretation of MIL-STD-1472G and that direct vision zones and the ground intercept matched the agreed upon interpretation for combining concepts presented in MIL-STD-1472G and SAE Recommended Practice J1050 (2009).

No issues were discovered during the verification of the model. The final outcome from the review was team consensus that the FHP: Driver CAD model passed verification.

2. PROBLEM STATEMENT

Military ground vehicles are currently designed using requirements from MIL-STD-1472G, the *Department of Defense Design Criteria Standard: Human Engineering*. The requirement to accommodate the central 90% of the Soldier population in which the fully equipped Soldier can sit safely and comfortably while performing all required functions, including driving, requires multivariate analysis methods so that both Soldier anthropometry and posture can be considered (DoD, 2012). MIL-STD-1472G is often open to interpretation and is therefore difficult for designers to apply consistently. Easy-to-use, valid design tools and procedures based on these methods are needed to effectively design vehicle workstations. The chosen tools are Computer-Aided Design (CAD) based accommodation models, Figure 1, adapted for Soldiers in military ground vehicles, that directly parallel long-standing SAE recommended practices used in the commercial automotive and truck domains (Zielinski, Huston II, Kozycki, Kouba, & Wodzinski, 2015). The first CAD model developed is the Tank Automotive Research, Development and Engineering Center (TARDEC) Fixed Heel Point (FHP): Driver CAD accommodation model, known throughout the rest of this report as the FHP: Driver CAD model.

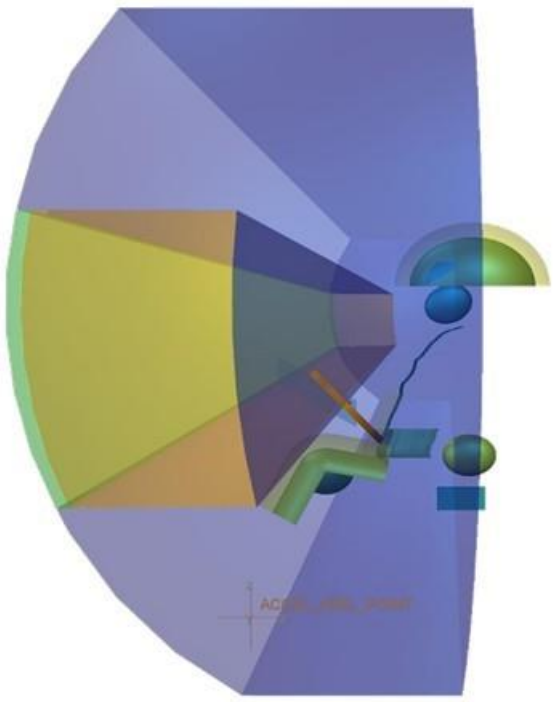


Figure 1: TARDEC Fixed Heel Point (FHP): Driver CAD Accommodation Model

2.1 INTENDED USE

The FHP: Driver CAD model described in this verification report is applicable to truck-like ground vehicles where driving is controlled via a conventional accelerator pedal and steering

wheel. The model may also be used in workstations that require the crew to interact with vehicle controls and non-driving displays using hands, horizontal directed vision, and adjustable seats.

The FHP: Driver CAD model is a parametric model that is intended to provide the composite boundaries representing the body of the defined target design population, including posture prediction. The boundaries defined include the required space and seat adjustments needed for the occupants' helmet, eyes, torso, knees, legs, and shins. Clearances between the occupant and surrounding interior vehicle surfaces have been added per MIL-STD-1472G (e.g. head clearance required from head (helmet) to vehicle roof line and thigh clearance to the steering wheel). Direct vision zones and ground intercept have been added based on MIL-STD-1472G and SAE Recommended Practice J1050, *Describing and Measuring the Driver's Field of View*, 2009.

It should be noted that CAD accommodation models serve as a design tool and are not intended to replace, but rather complement, Human Factors Engineering (HFE) assessment tools.

2.2 M&S OVERVIEW

The FHP: Driver CAD model is a statistical model created utilizing data collected in the *Seated Soldier Study* (2013) completed by the University of Michigan Transportation Research Institute (UMTRI). The original model, as provided by UMTRI, consists of a Microsoft Excel spreadsheet. The CAD version of the model was created using PTC Creo® 3D CAD software and is a stand-alone geometric reproduction of the output found in the UMTRI Microsoft Excel spreadsheet.

The primary model inputs describe the target driver population (a subset of the Army Anthropometric Survey (ANSUR) II) and the nominal location of the steering wheel. The target driver population is defined by gender mix, ensemble (clothing and equipment worn by the occupant), and the desired level of accommodation (e.g. 90%). The ensemble is selectable as either Personal Protective Equipment (PPE) which includes the Improved Outer Tactical Vest (IOTV) or Encumbered (ENC) which includes the PPE and Rifleman Ensemble, both of which are defined in the *Seated Soldier Study*. Ideally, the level of accommodation will be set at the central 90 percent of the target design population, to be consistent with MIL-STD-1472G requirements. The only vehicle input to the model is the location of the steering wheel, as determined by the Steering Wheel Point (SWP) (Zielinski et al., 2015).

The FHP: Driver CAD accommodation model represents the posture and position variability for the entire selected target design population (e.g. central 90%, 85% male). The model can guide vehicle designers in creating an optimized workspace for the occupant. The CAD accommodation model, along with additional added space claims for human factors, can be used to visualize MIL-STD-1472G requirements. This eliminates the concern that interpretations of the MIL-STD for creating occupant workspaces vary among vehicle designers (Zielinski et al., 2015).

2.3 M&S APPLICATION

The use of the FHP: Driver CAD model provides the opportunity to apply Human Systems Integration (HSI) very early in the acquisition process. The model can be utilized during the Material Solution Analysis Phase prior to Milestone (MS)A and through MSB. Past programs have not actively engaged HSI until MSB or the Engineering Manufacturing and Development (EMD) Phase, resulting in significant design and cost changes.

The FHP: Driver CAD model can be used to explore possible design tradeoffs when conflicts with other design parameters exist. Vehicle designers can use the model for the following scenarios: 1) during the concept and design phase of new acquisition programs, 2) while upgrading existing ground vehicle platforms, and 3) for assessing commercial off the shelf (COTS) systems. Human factors engineers could benefit by working with vehicle designers to perform virtual assessments in CAD when there is not enough time and/or funding to translate vehicle models into assessment software compatible formats and perform detailed human figure modeling.

2.3.1 MODEL ORIGIN

The Accelerator Heel Point (AHP) is the X and Z axis origin for the FHP: Driver CAD model. It is a reference point on the floor of the vehicle aft of the accelerator pedal. The AHP is constructed in side view using the undeflected accelerator pedal surface and the floor surface in the area of the pedal. AHP is defined by the intersection with the floor surface of a side-view line contacting the accelerator pedal surface and oriented at the Accelerator Plane Angle (APA) with respect to forward horizontal, Figure 2. APA is the angle with respect to forward horizontal of a reference plane used to define the accelerator heel point.

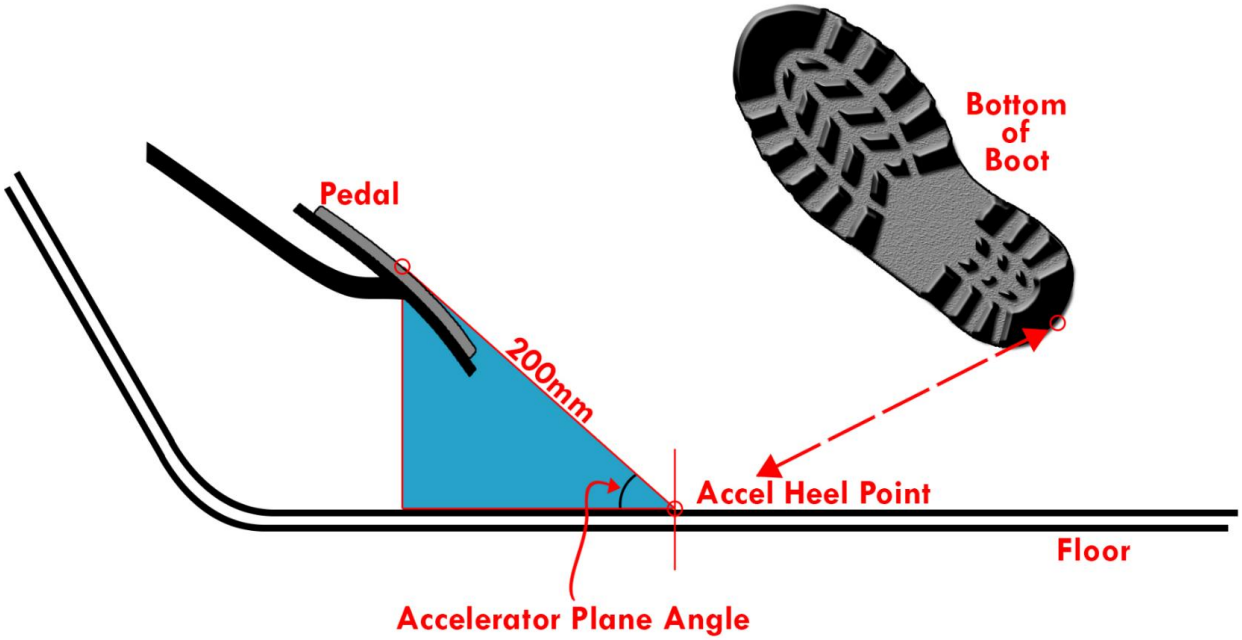


Figure 2: Accelerator Heel Point in CAD

2.3.2 MODEL INPUTS

Inputs to the FHP: Driver CAD model are shown below in Table 1. A sample of how the inputs appear in the model are shown in Figure 3.

Table 1: FHP Accommodation Model Inputs

Model Input	Description
Target Accommodation	The percentage of the target design population to be accommodated. The occupants not accommodated are evenly split between the smaller and larger extremes of the population. In MIL-STD-1472G (2012), the accommodation target has been set at 90%.
Fraction Male	The percentage of males in the defined target design population.
Ensemble	Clothing and equipment available for selection in the model: • [1]PPE = ACU + IOTV + ACH • [2]ENC = PPE + Rifleman Ensemble
Steering Wheel Point (SWP)	The SWP is the effective center of the steering wheel and is reported in horizontal and vertical components with respect to the AHP (Reed, 2005).
Consider Hydration Pack Relief	A seatback with hydration pack relief can fully accommodate an occupant's hydration pack such that the occupant's position in the seat is the same regardless of wearing a hydration pack. The following selections are available in the model: • Yes • No
Human Accommodation Reference Point (HARP) Measurement Tool	The expected distribution of driver-selected seat positions relative to the AHP is predicted based on the seat design HARP measurement tool selected. The two options of seat design HARP measurement tools are the SAE J826 H-point manikin and ISO 5353 Seat Index Point (SIP) tool (Reed & Ebert, 2014). The following selections are available in the model: • SAE J826 • ISO 5353
Consider Censored Seating	Occupant workspaces in vehicles and/or COTS seat does not always provide the ideal amount of horizontal and vertical seat travel (or location of seat travel) for the target design population. This function is offered to calculate loss of ideal occupant accommodation. The following selections are available in the model: • Yes • No
Seat Travel Reduction Front	The amount of reduced seat travel at the front of the seat track travel range window, reported in inches.
Seat travel Reduction Rear	The amount of reduced seat travel at the rear of the seat track travel range window, reported in inches.
Seat Travel Reduction Top	The amount of reduced seat travel at the top of the seat track travel range window, reported in inches.

Seat Travel Reduction Bottom	The amount of reduced seat travel at the bottom of the seat track travel range window, reported in inches.
Consider Ground Intercept	If ground intercept requirements can be determined with respect to the AHP, a ground intercept line (line of sight) can be shown. The following selections are available in the model: • Yes • No
Distance AHP to Vehicle Front	The distance from the AHP to the front of the vehicle, reported in inches.
Distance AHP to Ground	The distance from the AHP to the ground, reported in inches.
Minimum Ground Intercept	The value for minimum ground intercept to be calculated based on vehicle requirement, reported in inches.

[1] Personal Protective Equipment (PPE), Advanced Combat Uniform (ACU), Improved Outer Tactical Vest (IOTV) that included Enhanced Small Arms Protective Insert (ESAPI) plates, Enhanced Side Ballistic Inserts (ESBI), and Advanced Combat Helmet (ACH).
[2] Encumbered (ENC), Rifleman Ensemble defined in the Soldier Load Configurations in Ground Vehicles (McNamara, 2012) and Seated Soldier Study (Reed et al, 2013).

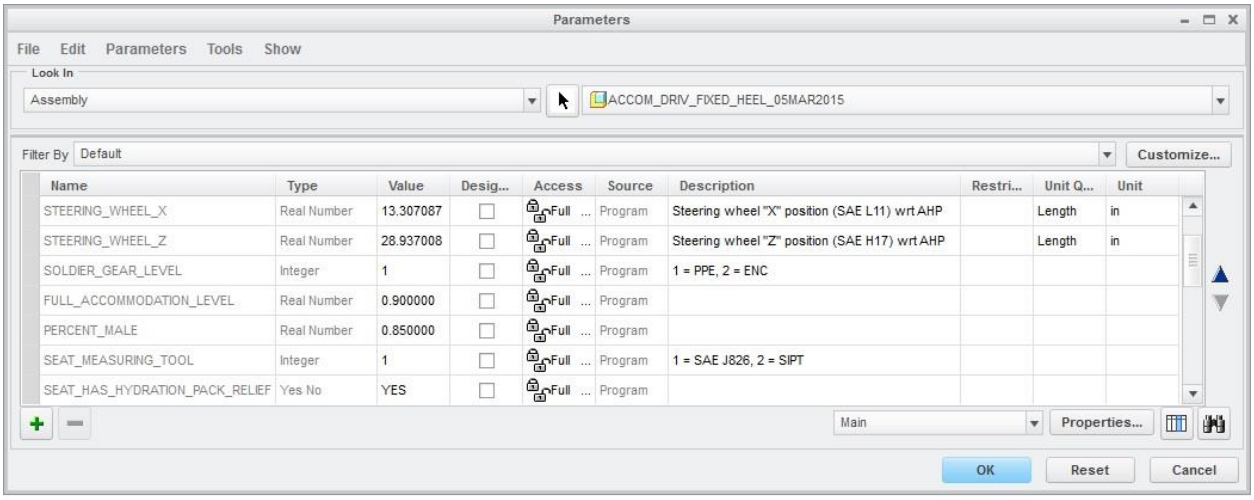


Figure 3: Example Input Parameter Table for FHP: Driver CAD model

2.3.3 MODEL OUTPUTS – SEAT TRAVEL AND OCCUPANT COMPOSITE BODY BOUNDARIES

The primary model outputs include the seat adjustment range needed to reach vehicle controls and the resulting positions for occupant population boundaries for eyes, helmet, torso, and knees. Model outputs are described below in Table 2 and shown in Figure 4.

Table 2: FHP: Driver CAD Model Accommodation Boundary Outputs and Definitions

Model Output	Description
Steering Wheel Preference Line	The steering wheel preference line depicts an acceptable range of Steering Wheel Points (SWPs) for the target driver population.
Steering Wheel Placeholder	The steering wheel placeholder represents the steering wheel used during data collection for

	the *Seated Soldier Study* but is not representative of a specific program steering wheel.
Seat Track Travel Range	The seat track travel range, shown in side view, represents the HARP travel path and boundaries of adjustments needed by the driver (Reed, 2015).
Seat Back Angle	A seat back angle adjustment range that will accommodate the desired fraction of the driver population (Reed, 2015).
Eyellipse	The eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of driver eye locations in the vehicle (Reed, 2015).
Helmet Boundary	The helmet boundary depicts the distribution of target design population helmet locations in the vehicle. The Advanced Combat Helmet (ACH) was used (Reed, 2015).
Torso Boundary ENC and Torso Boundary PPE	The torso boundary depicts the distribution of driver torsos, including the effects of ensemble (Reed, 2015).
Knee Boundary Including Leg and Thigh	The knee boundary with leg and thigh depicts the top, forward, and lateral distribution of the resting knee location in vehicle.
Elbow Boundary	The elbow boundary depicts the distribution of resting elbow locations of the occupant (Reed, 2016).
Accelerator Plane Angle (APA)	APA is the angle with respect to forward horizontal of a reference plane used to define the accelerator heel point.

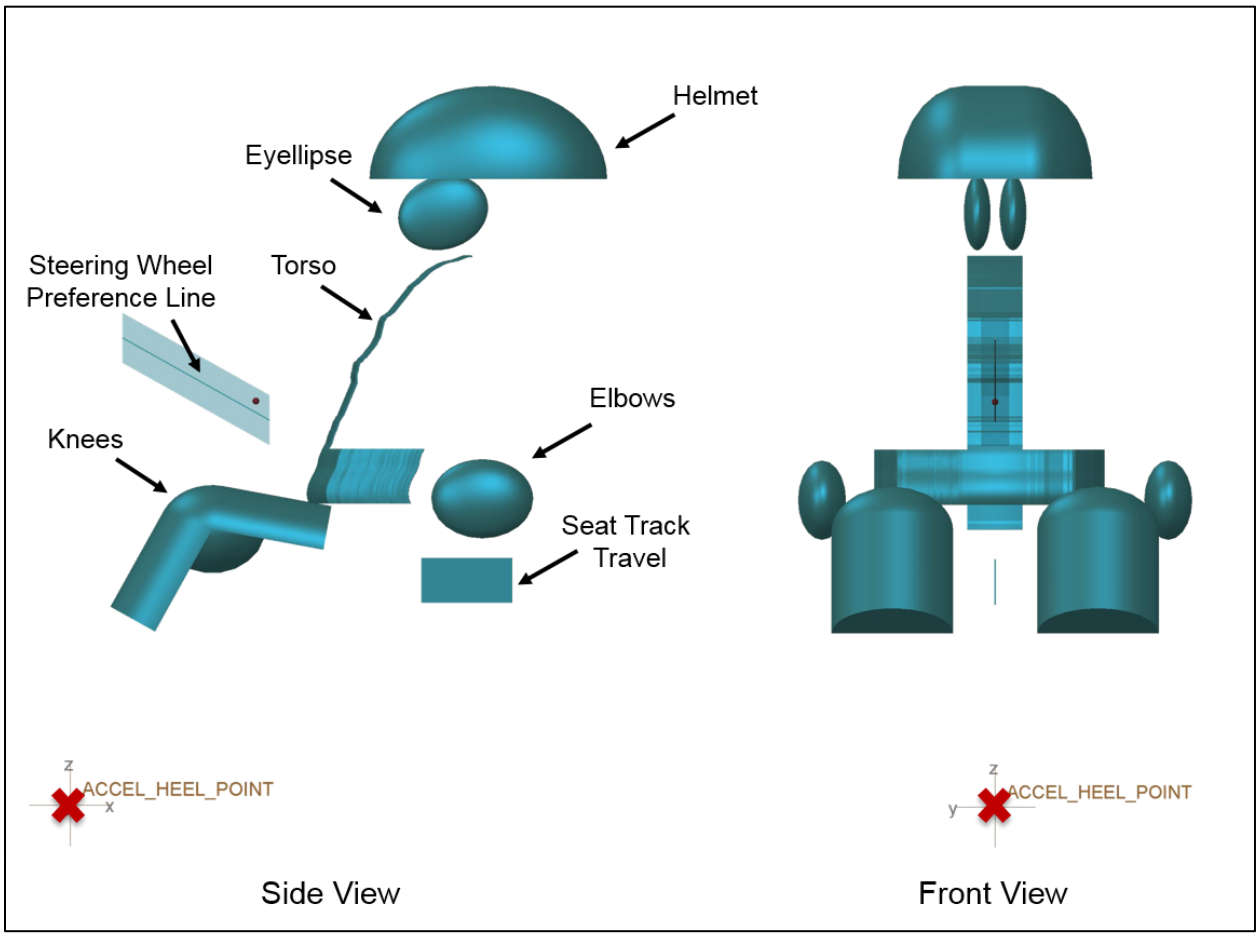


Figure 4: FHP: Driver CAD Model Example Output

2.3.4 MODEL OUTPUTS – OCCUPANT CLEARANCES BASED ON MIL-STD-1472

Clearance zones are included in the model to serve as a visual check for vehicle designers to utilize when creating the occupant workspace. Generally, 2 inches of clearance is required between the seated occupant and all vehicle structures and/or equipment. Model clearances are described below in Table 3 and shown in Figure 5.

Table 3: FHP: Driver CAD Model Clearance Outputs and Definitions

Model Output	Description
Clearance Helmet	Helmet clearance consists of an additional 2 inches of space claim required between the helmet boundary and the vehicle ceiling and nearby equipment.
Clearance Abdomen	Abdomen clearance consists of an additional 2 inches of space claim required between the seated occupant, with ensemble, and the steering wheel.
Clearance Knee, Leg, and Thigh	The knee, leg, and thigh clearance represents a 2 inch space claim required from the front

	and top of the knee and top and sides of legs and thighs to any surfaces such as the underside of the steering wheel or IP.
Clearance Elbow	Elbow clearance consists of an additional 2inches of lateral space claim required between the elbows, in a resting position, and nearby vehicle structures such as door trim.

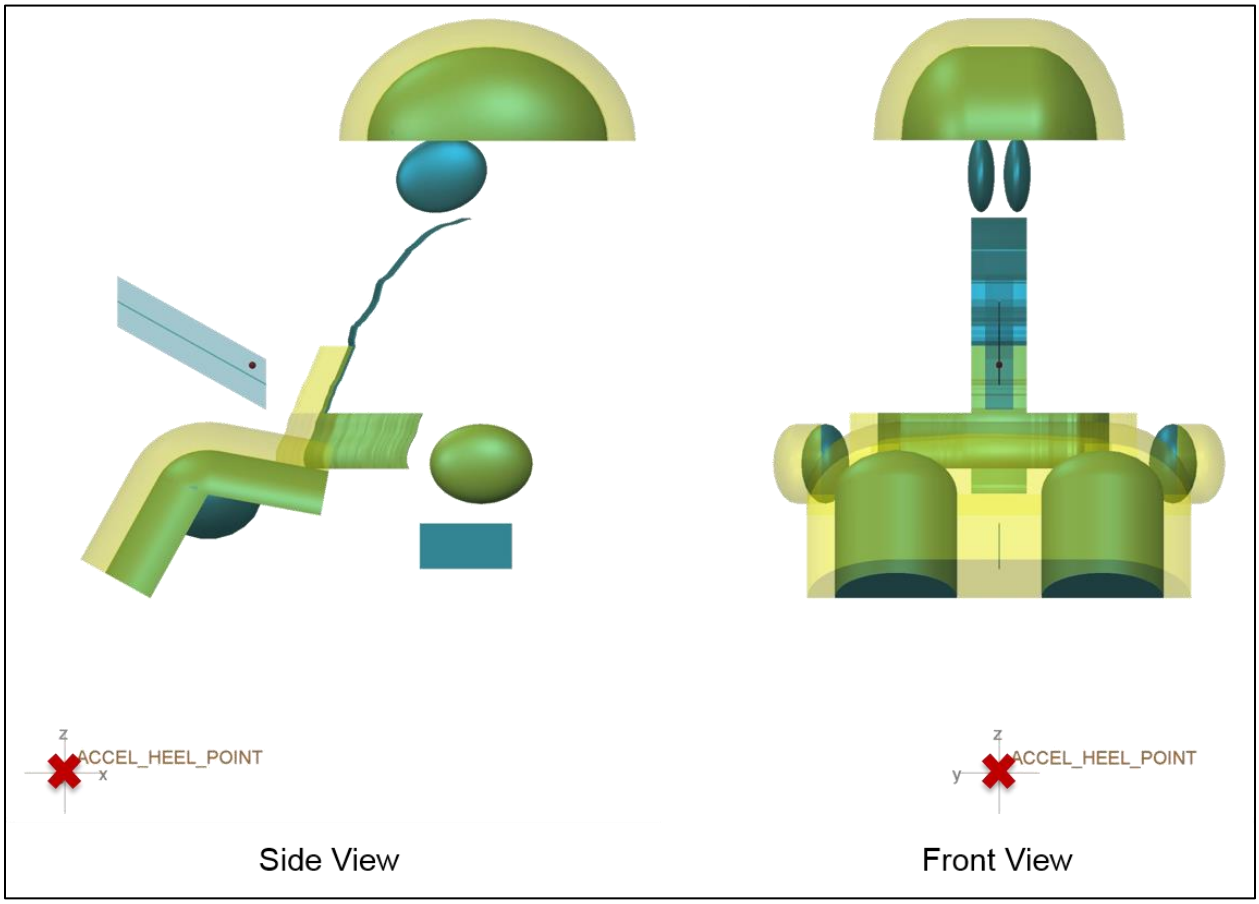


Figure 5: FHP CAD Accommodation Model Clearance Zone Outputs

2.3.5 MODEL OUTPUTS - DIRECT FIELD OF VIEW AND GROUND INTERCEPT BASED ON MIL-STD-1472 AND SAE J1050

The direct field of view has been divided into primary, secondary, and tertiary zones. The zones were developed with ARL HRED and UMTRI using a combination of vertical and horizontal visual fields described in MIL-STD-1472G and SAE J1050. When members of a population have different eye points, tangents to the eyellipse are used to determine field of view. (Huston II, Zielinski, & Reed, 2016). Model outputs are described below in Table 4 and shown in Figure 6, Figure 7, Figure 8.

Table 4: FHP: Driver CAD Model Vision Zone Outputs and Definitions

Model Output	Description
Vision Zone, Primary	The primary vision zone (Figure 6) indicates space viewable by all occupants from at least one eye using a minimum of "easy" eye rotation. Combining the limits of MIL-STD-1472G and SAE J1050, "easy" eye rotation is defined laterally as 15 degrees side-to-side from the occupant's centerline and vertically as +15/-30 degrees from horizontal (Huston II, et. al, 2016).
Vision Zone, Secondary	The secondary vision zone (Figure 7) includes both "easy" eye rotation and "easy" head turn. Combining the limits of MIL-STD-1472G and SAE J1050, "easy" eye rotation and "easy" head turn is defined laterally as 60 degrees side-to-side from the occupant's centerline (15 degrees eye + 45 degrees head) and vertically as +15/-30 degrees from horizontal (eye rotation only) (Huston II, et. al, 2016).
Vision Zone, Tertiary	The tertiary vision zone (Figure 8) includes both "max" eye rotation and "max" head turn. Combining the limits of MIL-STD-1472G and SAE J1050, "max" eye rotation and "max" head turn is defined laterally as 95 degrees side-to-side from the occupant's centerline (35 degrees eye + 60 degrees head) and vertically as +45 degrees/-65 degrees from horizontal (eye rotation only).

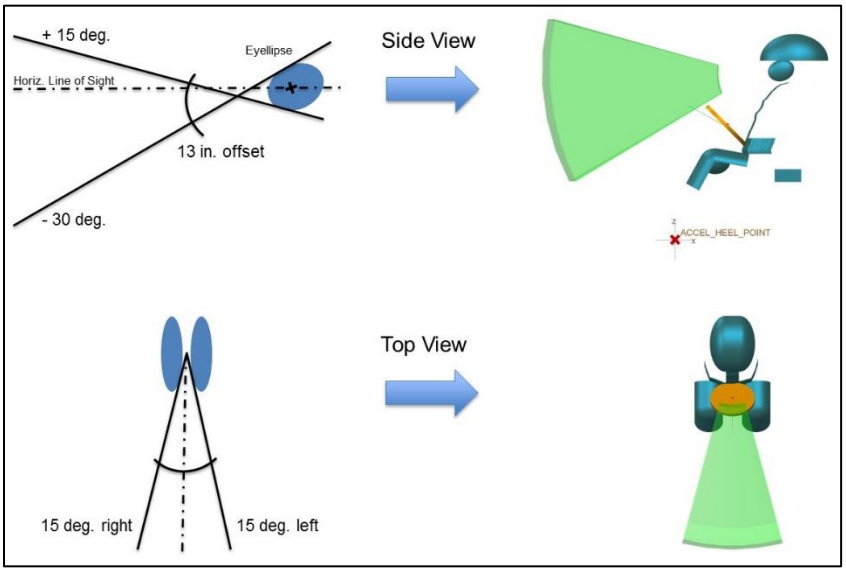


Figure 6: Primary Vision Using Eyellipse in Creo

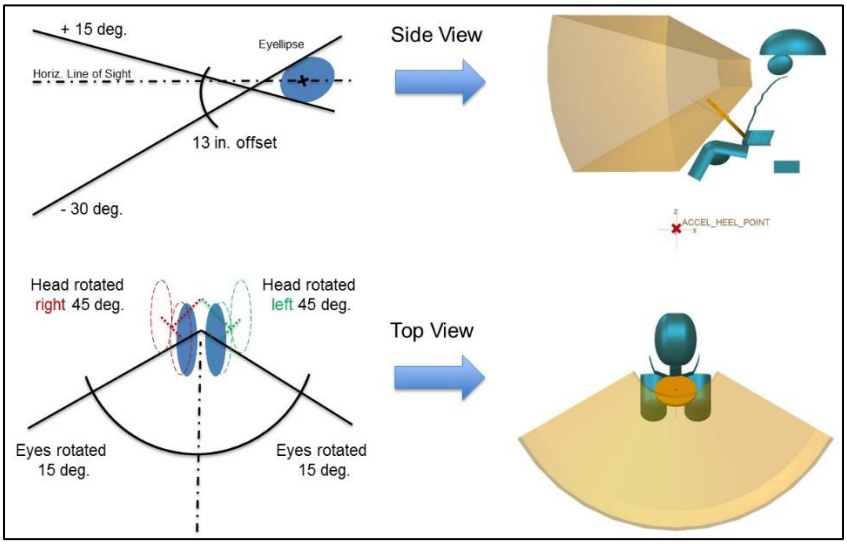


Figure 7: Secondary Vision Zone Using Eyellipse in Creo

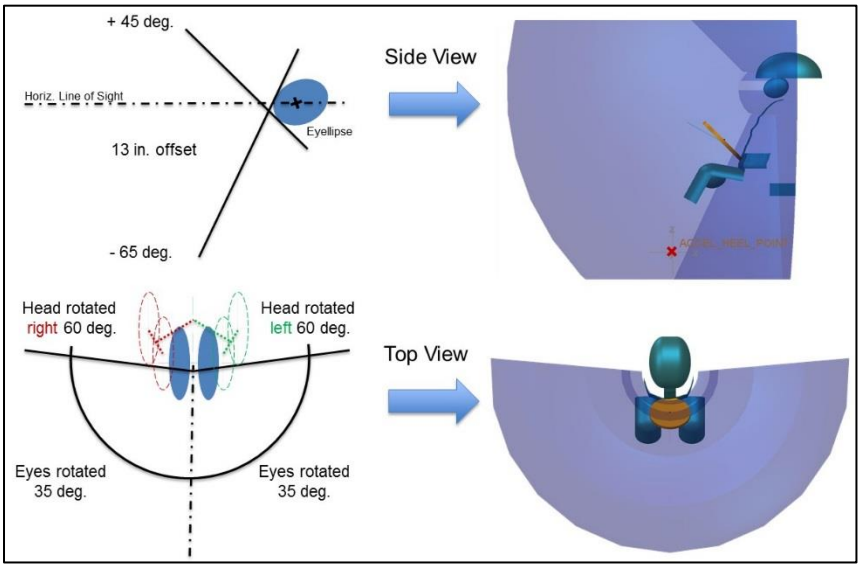


Figure 8: Tertiary Vision Zone Using Eyellipse in Creo

When the location of the occupant workspace is known with respect to the rest of the vehicle and the ground, the model is able to depict a best-case ground intercept using the eyellipse. An example of such a ground intercept is shown below in Figure 9. The tangent from the ground intercept to the lower side of the eyellipse represents the lowest sight line for the target population.

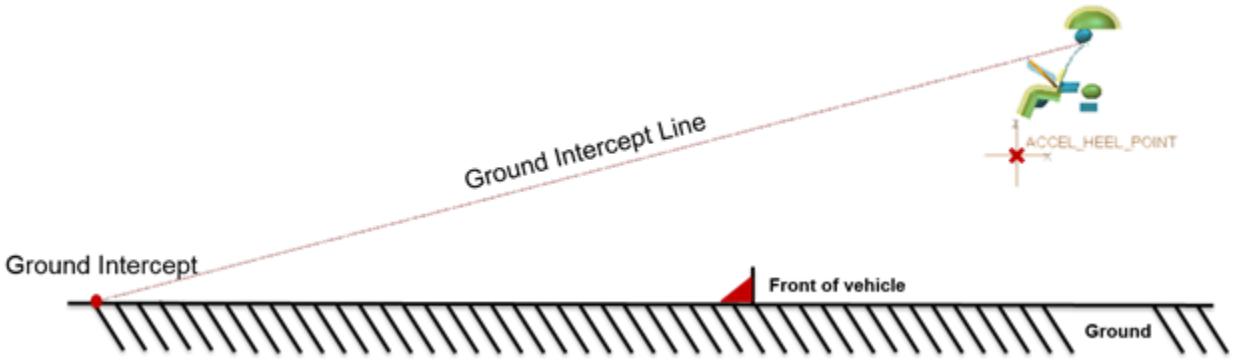


Figure 9: Ground Intercept Line Using Eyellipse in Creo

2.3.6 MODEL OUTPUTS - MANIKIN PLACEMENT

Using the same data underlying the creation of the accommodation boundaries, boundary manikins representing the anthropometric extremes of vehicle workstation design are placed in their nominal positions. This is helpful in understanding how specific individuals in the population fit into the vehicle and aids visualization for those unfamiliar with the accommodation boundaries (Huston II, et. al., 2016). Model outputs are described below in Table 5 and shown in Figure 10 for one of seven boundary manikins.

Table 5: Posture Prediction Model Output and Definitions based on Seated Soldier Study

Model Output	Description
Boundary Manikin Posture and Position	The Boundary Manikin Posture and Position predicts position and torso posture for a family of simulated drivers based on the vehicle configuration and the anthropometric inputs of stature, body weight, and erect sitting height (Reed, 2013).

Figure 10: Manikin Placement Using Posture Prediction Model

2.4 VERIFICATION SCOPE

This report documents the verification of the FHP: Driver CAD model, including the activities, results, and recommendations that were gathered during the verification effort. This report will be managed by the TARDEC accommodation model Project Lead and will be used to support any future enhancements to the FHP: Driver CAD model.

Verification of the model was performed on 01 August 2017 by the Verification Agents listed in Table 9, Section 7. TARDEC led the verification effort with participants from Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED), TARDEC Advanced Concepts Team (ACT), TARDEC Ground Vehicle Survivability and Protection (GVSP), TARDEC Center for System Integration (CSI), Marine Expeditionary Rifle Squad (MERS), and UMTRI.

The goal of verification was to evaluate the PTC Creo® 3D CAD version of the FHP: Driver CAD model, per the following:

1) Determine if the accommodation boundaries calculated by the TARDEC CAD model match those calculated by the UMTRI Microsoft Excel spreadsheet *Soldier Driver Accommodation Models 2017-06-08*

2) Determine if the clearance zones (helmet, abdominal, knees, legs, and shins) calculated by the TARDEC CAD model match the Subject Matter Expert (SME) interpretation of MIL-STD-1472G

3) Determine if the direct fields of view (primary, secondary, and tertiary) calculated by the TARDEC CAD model match the SME interpretation of MIL-STD-1472G and SAE J1050

4) Determine if the ground intercept calculated by the TARDEC CAD model matches the SME interpretation of the MIL-STD-1472G ground intercept requirement

5) Determine if the hip and eye points calculated by the TARDEC CAD model match those calculated by the UMTRI Microsoft Excel spreadsheet *Seated Soldier Posture Prediction 2014-09-01*

3. REQUIREMENTS AND ACCEPTABILITY CRITERIA

The FHP: Driver CAD model shall meet the requirements shown in Table 6 below:

Table 6: Requirements Relationship Table for Accommodation Model

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for input of the Steering Wheel Point (SWP) in "X" (horizontal) and "Z" (vertical) coordinates.	1.1 Input parameter is available for steering wheel position in X	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 Input parameter is available for steering wheel position in Z	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model allows for selection of seat hydration pack relief in the seat	2.1 Hydration pack relief selection of "yes" in model	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 Hydration pack relief selection of "no" in model	2.2 Representative (Pass) / Non-Representative (Fail)
3	Model allows for selection of either SAE J826 or ISO 5353 for the Human Accommodation Reference Point (HARP) measurement tool	3.1 HARP measurement tool selection of SAE J826 in model	3.1 Representative (Pass) / Non-Representative (Fail)
		3.2 HARP measurement tool selection of ISO 5353 in model	3.2 Representative (Pass) / Non-Representative (Fail)
4	Model allows for input of the population gender mix (e.g. 85% Male : 15% Female)	4.1 Fraction male input option in model	4.1 Representative (Pass) / Non-Representative (Fail)
5	Model allows for selection of ensemble as either PPE or ENC	5.1 Ensemble selection of PPE in model	5.1 Representative (Pass) / Non-Representative (Fail)
		5.2 Ensemble selection of ENC in model	5.2 Representative (Pass) / Non-Representative (Fail)
6	Model allows for a target population input (e.g. 90%)	6.1 Target accommodation input option in model	6.1 Representative (Pass) / Non-Representative (Fail)

7	Model predicts the Steering Wheel Preference Line	7.1 Model outputs a Steering Wheel Preference Line and SWP that adjusts with different inputs	7.1 Representative (Pass) / Non-Representative (Fail)
		7.2 TARDEC CAD model matches the UMTRI spreadsheet	7.2 Representative (Pass) / Non-Representative (Fail)
8	Model predicts a preferred steering wheel placement zone per guidance provided in the UMTRI paper *Preferred Steering Wheel Locations for Fixed-Heel-Point Driver Stations 2016-09-20* (fore/aft) and draft MIL-STD-1472H (side/side)	8.1 Model outputs a steering wheel placement zone that adjusts with different inputs	8.1 Representative (Pass) / Non-Representative (Fail)
		8.2 TARDEC CAD model matches the UMTRI spreadsheet and MIL-STD-1472H	8.2 Representative (Pass) / Non-Representative (Fail)
9	Model predicts the Accelerator Pedal Angle (APA)	9.1 Model outputs an APA that adjusts with different inputs	9.1 Representative (Pass) / Non-Representative (Fail)
		9.2 TARDEC CAD model matches the UMTRI spreadsheet	9.2 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the expected distribution of driver-selected seat positions relative to the accelerator heel point (AHP) based on the SAE J826 and ISO 5353 Seat Index Point (SIP) seat measurement tools	10.1 Model outputs fore/aft and vertical seat track travel window for a given population and gender mix that adjusts with different inputs	10.1 Representative (Pass) / Non-Representative (Fail)
		10.2 TARDEC CAD model matches the UMTRI spreadsheet	10.2 Representative (Pass) / Non-Representative (Fail)
11	Model predicts the expected (dis)accommodation of driver-selected seat positions relative to the accelerator heel point (AHP) if the seat travel is censored	11.1 Model outputs (dis)accommodation value of a censored seat travel that adjusts with model inputs	11.1 Representative (Pass) / Non-Representative (Fail)
		11.2 TARDEC CAD model matches the UMTRI spreadsheet	11.2 Representative (Pass) / Non-Representative (Fail)
12	Model predicts the seat back angle adjustment range	12.1 Model outputs a range of seta back angles measured from vertical and adjusts with different inputs for the population	12.1 Representative (Pass) / Non-Representative (Fail)
		12.2 TARDEC CAD model matches the UMTRI spreadsheet	12.2 Representative (Pass) / Non-Representative (Fail)
13	Model predicts the dimensions and location of the eyellipse with respect to AHP and mean seat travel	13.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with different inputs	13.1 Representative (Pass) / Non-Representative (Fail)
		13.2 TARDEC CAD model matches the UMTRI spreadsheet	13.2 Representative (Pass) / Non-Representative (Fail)
14	Model predicts the helmet contour boundary (helmet locations) with respect to the eye location and fitted to the eyellipse	14.1 Model outputs a helmet contour for the given population and gender mix that adjusts with the different inputs	14.1 Representative (Pass) / Non-Representative (Fail)
		14.2 TARDEC CAD model matches the UMTRI spreadsheet	14.2 Representative (Pass) / Non-Representative (Fail)
15	Model predicts the knee contour with leg and thigh segment angles based on location of resting drivers' knees in vehicle	15.1 Model outputs a knee ellipsoid for the given population and gender mix that adjusts with different inputs	15.1 Representative (Pass)/ Non-Representative (Fail)
		15.2 TARDEC CAD model matches the UMTRI spreadsheet	15.2 Representative (Pass)/ Non-Representative (Fail)
16	Model predicts torso contour with selected ensemble	16.1 Model predicts a torso contour with ensemble for the	16.1 Representative (Pass)/ Non-Representative (Fail)

		given population, gender mix, and ensemble configuration that adjusts with different inputs	
		16.2 TARDEC CAD model matches the UMTRI spreadsheet	16.2 Representative (Pass)/ Non-Representative (Fail)
17	Model predicts elbow contours based on location of resting drivers' elbows in vehicle	17.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	17.1 Representative (Pass)/ Non-Representative (Fail)
		17.2 TARDEC CAD model matches the UMTRI spreadsheet	17.2 Representative (Pass)/ Non-Representative (Fail)
18	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD-1472G requirements	18.1 Model outputs a 2" clearance zone from the top of the helmet contour that adjusts with the different inputs	18.1 Representative (Pass) / Non-Representative (Fail)
19	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472H draft recommendations	19.1 Model outputs a 2" clearance zone from the top and front of the knee contour and the front of the leg segment and top of the thigh (in side-view) and adjusts with different inputs	19.1 Representative (Pass) / Non-Representative (Fail)
20	Model provides a clearance zone for the torso boundary, with selected ensemble, based on MIL-STD-1472H draft recommendations	20.1 Model outputs a 2" clearance zone forward from the torso boundary and adjusts and adjusts with the different inputs	20.1 Representative (Pass) / Non-Representative (Fail)
21	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472H draft recommendations	21.1 Model output provides a 2" clearance zone laterally for the resting elbow contours	21.1 Representative (Pass)/ Non-Representative (Fail)
22	Model provides direct field of view (primary, secondary, and tertiary zones) based on MIL-STD-1472G and SAE J1050	22.1 Model outputs primary vision zone that adjusts with model inputs	22.1 Representative (Pass)/ Non-Representative (Fail)
		22.2 Model outputs secondary vision zone that adjusts with model inputs	22.2 Representative (Pass)/ Non-Representative (Fail)
		22.3 Model outputs tertiary vision zone that adjusts with model inputs	22.3
23	Model provides a ground intercept	23.1 Model outputs a line tangent to the bottom of the eyellipse to the ground and adjusts with different user inputs	23.1 Representative (Pass)/ Non-Representative (Fail)

Along with using the FHP: Driver CAD model, ground vehicle designers will use boundary manikins when creating the interior workspace. The boundary manikins are postured and positioned in CAD using equations from the posture prediction model created by UMTRI. The requirements for posture prediction are shown in Table 7 below:

Table 7: Requirements Relationship Table for Posture Prediction of Boundary Manikins

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the AHP	1.1 Model outputs the location of the hip with respect to the AHP that matches the UMTRI spreadsheet	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the AHP	2.1 Model outputs the location of the eye with respect to the AHP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

Numerical values calculated by both the TARDEC CAD model and the UMTRI Microsoft Excel spreadsheets must match within +/- 0.100 inches or +/- 0.100 degrees to be considered equivalent.

4. CAPABILITIES, LIMITATIONS, & ASSUMPTIONS (CLA), RISKS/IMPACTS

4.1 M&S CAPABILITIES

The FHP: Driver CAD model will provide government and industry partners with the following M&S capabilities:

- Seat travel (positioned in-vehicle) and seat back angle
- Relevant population boundaries for occupant posture in a crew workstation
- Posture prediction for the identified boundary manikins
- Clearances based on interpretation of MIL-STD-1472G
- Direct Field-of-View (FOV) based on a combination of vertical and horizontal visual fields from MIL-STD-1472G and SAE J1050
- Ground intercept based on interpretation of MIL-STD-1472G

4.2 M&S LIMITATIONS

The FHP: Driver CAD model has limitations based on the ground vehicle requirements for the crew workspace, as follows:

- Predicts fixed heel point driving conditions only (and limited commander positions) and does not address other special driving conditions such as fixed eye point (FEP), open protected or out-of-hatch (OOH) positions
- Cannot be used if a fixed seat back angle is required for the crew positions
- Cannot be used if horizontal and vertical seat travel are not integrated into the seat design

- Predicts where the occupant ideally wants to posture and position themselves but does not take into consideration posture changes due to restricted environments such as small transparent armor, low ceiling height, etc.
- Specific set of ensembles were defined for model creation. If clothing and equipment requirements for the program deviate greatly from the available selections in the model, a review of the details of the ensemble will need to be completed to confirm the model's applicability.

4.3 M&S ASSUMPTIONS

The development of a valid FHP: Driver CAD model is based on the following assumptions:

- The fixtures created and used by UMTRI to collect the occupant data are representative of a fixed heel point driver workspace
- Analysis methods used by UMTRI accurately predict occupant preferred posture and position
- Position data collected in a static environment over a short period of time are reasonably similar to occupants' preferred postures and positions during long-duration driving

4.4 M&S RISKS/IMPACTS

The constraints and limitations highlighted above could potentially result in an interior workspace design that is not fully optimized. This risk will be mitigated by Subject Matter Experts (SMEs) from ARL HRED who complete human factors assessments on the proposed designs, COTS vehicles, and demonstrators during the acquisition process per IAW AR 602-2. This assessment will be captured in documentation completed by the ARL HRED SMEs.

5. VERIFICATION TASK ANALYSIS

5.1 DATA VERIFICATION TASK ANALYSIS

No specific data verification tasks were completed because UMTRI, as the data developer, documented the methods and results of the data collection. The data and statistical techniques employed by UMTRI are appropriate for the creation of the models. Standard anthropometric data, which correlated to ANSURII data, was collected on the study participants. A whole-body laser scanner was used to record body shape in both seated and standing postures. Statistical analysis of body landmark data was conducted by UMTRI and validation of the data for the models to predict occupant posture, as a function of vehicle factors, was completed (Reed, et al, 2013). The UMTRI documents capturing this work are listed below:

- Seated Soldier Study: Posture and Body Shape in Vehicle Seats, Final Report UMTRI-2013-13
- Development of Accommodation Models for Soldiers in Vehicles, Final Report UMTRI-2014-26

- Seated Soldier Elbow Clearance Zones, 2016-12-10
- Preferred Steering Wheel Locations for Fixed-Heel-Point Driver Stations, 2016-09-20
- Soldier Driver Accommodation 2017-06-08, UMTRI Excel spreadsheet
- Seated Soldier Posture Prediction 2014-09-01, UMTRI Excel spreadsheet

The information provided by UMTRI was utilized to create the FHP: Driver CAD model.

5.2 MODEL VERIFICATION TASK ANALYSIS

Model verification included a total of ten tests, shown below in Table 8, to compare outputs from the FHP: Driver CAD model to the UMTRI Soldier Driver Accommodation (2017) spreadsheet and Seated Soldier Posture Prediction (2014) spreadsheets. The highlighted values in the table indicate which inputs were changed from the previous test.

Table 8: FHP: Driver Accommodation Model Test Matrix

Test #	Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
				X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
1	90%	90%	PPE	8.9	30.9	No	SAE J826
2	90%	90%	PPE	**14.8**	30.9	No	SAE J826
3	90%	90%	PPE	**13.3**	**29.0**	No	**ISO 5353**
4	90%	90%	PPE	**11.8**	29.0	No	**SAE J826**
5	90%	90%	PPE	**17.7**	**27.0**	No	SAE J826
6	90%	90%	**ACU**	**13.3**	**29.0**	No	SAE J826
7	**95%**	90%	**ENC**	13.3	29.0	No	SAE J826
8	**90%**	**50%**	**PPE**	13.3	29.0	No	SAE J826
9	90%	50%	**ACU**	13.3	29.0	No	SAE J826
10	90%	50%	**ENC**	13.3	29.0	**Yes**	SAE J826

Tests #1-6 primarily explore the effects of varying the Steering Wheel Point (SWP)

- Geometry and position for the Steering Wheel Preference Line and Steering Wheel Zone are constant (because the underlying population remains the same across these tests)
- Geometry for Seat Track Travel and composite body boundaries (except knees) is constant, but position varies
- Knee Boundary geometry and position are unique for each test to reflect changing shin and thigh angles
- Changing the HARP measurement tool only affects the position of Seat Track Travel

Test #7 primarily explores the effects of varying Target Accommodation

- Geometry for Seat Track Travel and composite body boundaries increase in size with increased Target Accommodation

Tests #8-10 primarily explore the effects of using a different gender mix (Fraction Male) and varying the Ensemble

- Geometry for Seat Track Travel and composite body boundaries decrease in size with a smaller proportion of males. This is because women are generally smaller than men.
- Position for Seat Track Travel and composite body boundaries vary with the chosen ensemble. This is because Soldier tend to put their bodies in the same position regardless of the ensemble worn. They move the seat to make up for displacement caused by their worn equipment.

Results from the above tests have been reported both in terms of passing or failing the requirements and acceptability criteria presented previously in Section 3 and screenshots showing how calculated numerical results were translated into CAD and compare to UMTRI's results. Please refer to the following appendices:

- Appendix B – Requirements and Acceptability Criteria Results
- Appendix G - Initial Task Analysis

6. VERIFICATION RECOMMENDATIONS

Team consensus from the verification event is that the FHP: Driver CAD model passed verification with no outstanding issues requiring corrective action. The following recommendations, applicable to the FHP: Driver CAD model and/or future planned accommodation models, were discussed by the team during the review:

- Steering Wheel Placement
  - Understand acceptable variability of steering wheel angle and diameter (requires funding to complete a study)
  - Create design criteria for steering wheel placement and add to design guide
  - Create design guidance for occupant egress with respect to steering wheel placement (may require funding to complete a study)
  - Create zones for pedal placement (requires funding to complete a study)
- Accelerator Plane Angle
  - Add a note to the user guide clarifying that the Accelerator Heel Point (AHP) in the CAD model is different than the heel point of accelerator mentioned in Table XXX, item #7 of MIL-STD-1472
- Seat Track Travel
  - Establish a means to determine the amount of vertical seat travel needed to achieve a specific ground intercept and define the process in the user guide
- Helmet Contour
  - During development of the Fixed Eye Point (FEP): Driver model, consider the number of vision blocks needed and adjust the helmet contour accordingly to account for any additional head turn (may require funding for a study)

    - Confirm that the FHP helmet contour was developed using methodology from SAE Recommended Practice J1052 and note this fact in the user guide
- Elbow Contour
    - During development of the FEP: Driver model, consider adding rearward elbow clearance
    - In future accommodation modeling efforts, consider situations that affect elbow position such as the use of keyboards or obstacles such as nearby seat posts. Review the clearance zone that will be created for the Fixed Seat: Non-Driver model with human factors SMEs
    - Make any necessary adjustments to the FHP: Driver CAD model after the FEP and Fixed Seat models have been completed
    - Apply the FHP: Driver CAD model to the M-ATV CAD to determine if the clearance zone would have predicted interference with the door as currently seen in theatre
- Vision Zones
    - In the user guide, explain the development of min/max vision zone distances
    - In the user guide, explain how head turn was taken into account in the development of the vision zones (reference SAE Recommended Practice J1050)
- Ground Intercept
    - In the user guide, explain how to use the model's ground intercept function to explore various ground intercept values
    - Consider adding an up vision line to top of window similar to the ground intercept selection

The Verification Agents presented the team with the following recommended next steps for the FHP: Driver CAD model:

- Dissemination of the model
    - Load the model into PDMLink for internal use and for use by authorized U.S. Government Agencies and their contractors who are on Government contract or have a valid need to know
    - Submit model for OPSEC and load the approved version on TARDEC's public facing website (under development as of this writing) for all other potential users
- Documentation of the model
    - Complete the *TARDEC FHP: Driver CAD Accommodation Model Verification Report*, submit for OPSEC, and load the approved version to DTIC
    - Develop a user guide for the model that includes HFE design guidance input from ARL HRED, and load it to both PDMLink and TARDEC's public facing website (a version approved through OPSEC)
- Further model development

- Working with UMTRI, develop a process to define the Human Accommodation Reference Point (HARP) for use when only seat CAD, but not physical seats, is available (requires funding to complete a study)
- Determine final approach, funding, and timing necessary to complete model validation

7. KEY PARTICIPANTS

Table 9 identifies the participants involved in the verification effort, including their roles and responsibilities.

Table 9: Key Participants for FHP: Driver CAD Model Verification Effort

Verification Function	Description	Responsible M&S
M&S Proponent	The organization that has primary responsibility for M&S planning and management that includes development, verification and validation, configuration management, maintenance, use of the model or simulation, and others as appropriate. A Government entity.	Frank J. Huston II, TARDEC ACT Gale. L. Zielinski, TARDEC ACT
M&S User	The individual, group, or organization that uses the results or products from a specific application of the model or simulation.	Gary L. Bronstetter, TARDEC ACT Kenneth M. Reeves, TARDEC ACT Gale M. Litrichin, TARDEC GVSP Eric S. Paternoster, TARDEC CSI ARL HRED Government Contractors
Verification Agent	The organization designated by the M&S proponent to perform verification of a model, simulation, or federation of M&S.	Frank J. Huston II, TARDEC ACT Gale L. Zielinski, TARDEC ACT
M&S Developer	The individual, group or organization responsible for developing or modifying a model or simulation in accordance with a set of design requirements and specifications.	Frank J. Huston II, TARDEC ACT Matthew P. Reed, Ph.D, UMTRI
SMEs	Individual who, by virtue of education, training, or experience, has expertise in a particular technical or operational discipline, system, or process.	Frank J. Huston II, TARDEC ACT Gale L. Zielinski, TARDEC ACT Cheryl A. Burns, ARL HRED Richard W. Kozycki, ARL HRED Joseph R. Urda, ARL HRED David A. Hullinger, ARL HRED Brian D. Corner, PhD, MERS - SIAT Matthew P. Reed, Ph.D, UMTRI

8. ACTUAL VERIFICATION RESOURCES EXPENDED

8.1 VERIFICATION RESOURCES EXPENDED

Table 10 identifies the resources used to create the TARDEC FHP: Driver CAD model and complete associated activities, including verification.

Table 10: Verification Resources

Document/Deliverable	Required Resources	POC
FHP: Driver Accommodation Model Proof of Concept	M&S Developer and SME support	TARDEC ACT
The Seated Soldier Study: Posture and Body Shape in Vehicle Seats Final Report	M&S Developer and SME support	UMTRI
Seated Soldier Posture Prediction Excel Spreadsheet	M&S Developer and SME support	UMTRI
Development of Accommodation Models for soldiers in Vehicles – Driver Final Report	M&S Developer and SME support	UMTRI,
FHP: Driver Accommodation Model Alpha Build	SME support	TARDEC ACT
FHP: Driver Accommodation Model Proof of Concept Introduction Report	SME support	TARDEC ACT
FHP: Driver Accommodation Model Funding Approval for FY16	SME support	TARDEC ACT
Soldier Driver Accommodation Model Excel Spreadsheet	M&S Developer and SME support	UMTRI
FHP: Driver Verification and Validation Plan	Verification Agent, M&S Developer and SME support	TARDEC ACT
FHP: Driver Accommodation Model Funding Approval (FY17)	SME support	TARDEC ACT
FHP: Driver Accommodation Model MOA (ARL HRED/TARDEC)	SME support	ALR HRED
FHP: Driver Accommodation Model Beta Build	SME support	TARDEC ACT
FHP: Driver Accommodation Model Verification packet completed	M&S Developer and Verification Agent	TARDEC ACT, UMTRI
FHP: Driver Model Release into PDMLink	SME support	TARDEC ACT
FHP: Driver Verification Report Revision 1.0	Verification Agent, Validation Agent, M&S Developer and SME support	TARDEC ACT

8.2 ACTUAL VERIFICATION MILESTONES AND TIMELINE

Table 11 identifies the major milestone achievements in the creation the FHP: Driver CAD model and completion of associated activities, including verification.

Table 11: Verification Milestone Timeline

Document/Deliverable	Delivery Date
FHP: Driver CAD Model Proof of Concept	February 2013
Posture Prediction Final Spreadsheet	September 2014
FHP: Driver Accommodation Model Final Report from UMTRI	September 2014
FHP: Driver CAD Model Alpha Build	December 2014
FHP: Driver Verification and Validation Plan	February 2016
FHP: Driver Model Final Accommodation Model Spreadsheet	February 2016
FHP: Driver CAD Model Beta Build	December 2016
FHP: Driver Verification and Validation Plan – RevA	January 2017
Functional Posture integrated with CAD Boundary Manikins	March 2017
FHP: Driver CAD Model Verification Complete	August 2017
FHP: Driver CAD Final Model Release into PDMLink	November 2017
Verification Report (Final)	November 2017

9. VERIFICATION LESSONS LEARNED

Verification of the FHP: Driver CAD model marks the first time that TARDEC has verified such a product. Before the verification event, the M&S Proponents and Developers determined that verifying CAD outputs against UMTRI's spreadsheet, given the number of calculations involved, would be too time intensive to complete in front of a live audience. Alternatively, a PowerPoint document (see Appendix G - Initial Task Analysis) was compiled for early distribution to all participants. This gave participants flexibility to focus on tests of particular interest during the verification event.

10. APPENDICES

10.1 APPENDIX A – M&S DESCRIPTION

10.1.1 M&S DEVELOPMENT AND STRUCTURE

The information in this Appendix is extracted from *Creation of the Driver Fixed Heel Point (FHP) CAD Accommodation Model for Military Ground Vehicle Design* (2016).

Ensuring that a given percentage of the population can sit safely and naturally while performing all required functions, including driving, requires multivariate analysis methods that consider the physical dimensions of the Soldier (anthropometry) and behavioral effects (posture) in a three dimensional space (DoD, 2012). This analysis is available for the FHP: Driver position as Soldier-specific statistical population accommodation models, developed by UMTRI, that parallel long-standing Society of Automotive Engineers (SAE) recommended practices used in the commercial automotive and truck domains. Because vehicle designs are developed from the early concept stages forward using CAD software, UMTRI's work has been encoded into a parametric CAD template that adjusts based on user inputs describing the Soldier population, desired accommodation level, and vehicle environment.

The primary developments that have made it possible to create a reusable CAD template representing FHP accommodation are UMTRI's predictive models for Soldier posture and the utilization of automated design capabilities available in many current CAD systems.

The automotive industry began introducing statistical population models into vehicle design in the 1960s to better understand various aspects of driver posture. The Seated Soldier Study (Reed and Ebert, 2013) was completed to capture Soldier preferred posture and position data in a driver mockup while considering the unique ground vehicle workstation environment and the clothing and equipment ensembles worn by Soldiers.

The Seated Soldier Study gathered data on 145 enlisted men and women as drivers at three Army posts. Soldiers wore three levels of clothing and equipment including: 1) the advanced combat uniform (ACU), consisting of the Soldier's own jacket, trousers, shirt, and combat boots; 2) personal protective equipment (PPE), consisting of the ACU plus an Improved Outer Tactical Vest (IOTV), Enhanced Small Arms Protective Insert (ESAPI) plates, Enhanced Side Ballistic Inserts (ESBI), and an Advanced Combat Helmet (ACH); and 3) encumbered (ENC), consisting of the ACU and PPE, plus a hydration pack and a Tactical Assault Panel (TAP) with a Rifleman equipment kit (Reed and Ebert, 2013).

The driver mockup simulates a Fixed Heel Point (FHP) driver workstation, including an accelerator pedal, steering wheel, and adjustable seat. When Soldiers entered the driver mockup, they found their preferred driving position by adjusting the seat's fore-aft (horizontal) and up-down (vertical) positions, as well as seat back angle. Each Soldier's posture and seat position was then digitized.

UMTRI's analysis of the data yielded both the average postures for individuals as a function of their body size and equipment level and accommodation boundaries capturing posture variability for everyone across the target population. In particular, the accommodation boundaries indicate the seat adjustment range needed to reach vehicle controls and the resulting positions for the equipped Soldier population's eyes, helmet, torso, and knees. Working models were provided by UMTRI in the form of Microsoft Excel spreadsheets. For a more in-depth discussion of UMTRI's work, please refer to the Seated Soldier Study (Reed and Ebert, 2013) and Development of Accommodation Models for Soldiers in Vehicle — Driver (Zerehsaz et. al., 2014).

The CAD version of the FHP: Driver accommodation model was created by TARDEC ACT using PTC Creo® 3D CAD software. Functionally, the foundation of the model is a stand-alone geometric reproduction of UMTRI's Microsoft Excel spreadsheets. Clearances between the Soldier population and surrounding interior vehicle surfaces were layered onto the model per the intent of MIL-STD-1472G, along with direct vision zones and a ground intercept tool that incorporate concepts from both MIL-STD-1472G and SAE Recommended Practice J1050, *Describing and Measuring the Driver's Field of View*, 2009. To aid in understanding how workstation design affects individuals, boundary manikins representing the anthropometric extremes for workstation design were placed in their predicted postures.

After building a static version of the accommodation model (i.e., a single instance of the possible combinations of Soldier population, desired accommodation level, and vehicle environment inputs), the process of automating the model began. This was done using a tool within Creo known as Pro/PROGRAM. Most CAD users already take advantage of the parametric nature of today's design software. For example, depending on how a model is constructed, simple changes can be propagated throughout by delving into a model's geometry and modifying dimensions. Pro/PROGRAM takes this concept a step further and allows for control of a model from outside the model tree, using relations and rules. End users of the FHP: Driver accommodation model are able to modify a list of parameters that are tied to the underlying geometry. Logical expressions are used to determine which portions of the Pro/PROGRAM code to execute for a given set of input values.

UMTRI's spreadsheets provide the values necessary to reproduce the relatively simple geometric elements comprising the accommodation boundaries (e.g. centroids and axis lengths for several ellipsoids). It was possible to encode the equations from UMTRI's spreadsheets into Creo without modification or the need for further calculations, with two notable exceptions. Because the majority of human anthropometric dimensions are normally distributed, the standard normal cumulative distribution function (CDF) is used throughout UMTRI's work to determine values at the desired level of accommodation. Creo does not contain an equivalent to Microsoft Excel's NORM.DIST function, so the following logistic approximation, having a maximum error of

0.00014 at z = ± 3.16, was used instead (Bowling, Khasawneh, Kaewkuekool, and Rae Cho, 2009).

$$F(z) \sim \frac{1}{1 + e^{-(0.07056 * z^3 + 1.5976 * z)}}$$

The second exception involves the positioning of manikins. UMTRI provides coordinates of body landmarks with respect to the geometric origin of the accommodation model (i.e. the AHP, the lowest intersection of the manikin's heel with the floor when the foot is on the undepressed accelerator pedal) sufficient to locate the hips, torso articulation, and head. To place these coordinates into the reference systems of the boundary manikins (an axis system located between the hips of each manikin and aligned with the torso) and calculate the joint angles needed to position the limbs in three-dimensional space, Euclidean transformations for both translation and rotation were used.

10.1.2 M&S USE HISTORY

10.1.2.1 PROOF OF CONCEPT

The proof of concept for the FHP: Driver CAD model was created for the Occupant Centric Platform (OCP) Technology Enabled Capability Demonstration (TECD). The underlying accommodation modeling, based on the commercial large truck environment (Class-B vehicles), was originally developed by UMTRI for the International Truck and Engine Corporation. This model was the closest match in UMTRI's repertoire to any Army ground vehicle applications. The proof of concept CAD model was applied to the OCP Light Demonstrator concept. More detailed information regarding the development and use of the proof of concept CAD FHP: Driver model can be found in the *OCP TECD Report Introduction to Boundary Manikins and Accommodation Models for Military Ground Vehicle Occupant Centric (OC) Design* (2015).

10.1.2.2 ALPHA VERSION

The alpha version of the FHP: Driver CAD model has two primary distinctions from its predecessor. First, it is based on empirical Soldier data from the *Seated Soldier Study* instead of the U.S. civilian truck driver population. Second, all of the data and calculations from UMTRI's Microsoft Excel spreadsheets are encoded in the model to allow for standalone operation. The alpha version of the FHP: CAD model was applied to the Joint Tactical Transportation System (JTTS), created at TARDEC. The model provided valuable feedback to the CAD M&S Developer regarding questions ground vehicle designers may have concerning the limits of the model and required user inputs. The CAD model was based on the following documents:

- UMTRI-2013-13, *Seated Soldier Study: Posture and Body Shape in Vehicle Seats*, Final Report dated October 2013
- UMTRI-2014-26, *Development of Accommodation Models for Soldiers in Vehicles*: *Driver*, Final Report dated September 2014

- UMTRI Microsoft Excel spreadsheet, *Soldier Driver Accommodation Models 2017-05-03*
- UMTRI Microsoft Excel spreadsheet, *Seated Soldier Posture Prediction 2013-11-30*

10.1.2.3 BETA VERSION

The beta version of the FHP: Driver CAD model has not yet been applied to a program. The model, however, has been updated to include additional data provided from the *Seated Soldier Study* related to elbows, legs, and shins, and includes SME interpretation of MIL-STD-1472 and SAE J1050. This model will transition to a final release upon the completion of verification.

10.1.3 CONFIGURATION MANAGEMENT

The Advanced Concepts Team (ACT) will manage any changes to the FHP: Driver CAD accommodation model and upload the latest version.

The FHP: Driver CAD accommodation model is released in PDMLink at the following location:

Libraries > STANDARD CAD TEMPLATE LIBRARY, 19207 > Accommodation

The following top assemblies have been released:

12629792 TARDEC Fixed Heel Point Driver 19207_12629792

Questions related to the CAD model development and application should be sent to:

TARDEC Advanced Concepts Team
6501 E. 11 Mile Road
Bldg 200, RDTA-SIE-SE-AAC-TI-TICON
MS 207
Warren, MI 48397-5000

Gale L. Zielinski (Project Lead)
Office: (586) 282-5287
E-mail: gale.l.zielinski.civ@mail.mil

Frank J. Huston II (Model Developer)
Office: (586) 282-5657
E-mail: frank.j.huston.civ@mail.mil

10.2 APPENDIX B – REQUIREMENTS AND ACCEPTABILITY CRITERIA RESULTS

The requirements and acceptability criteria results for accommodation and posture prediction are shown below in Table 12 and Table 13, respectively. Metrics are noted as pass or fail. None of the metrics produced a failing result, so no corrective action plans are required.

Table 12: Accommodation Model Requirements Results

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for input of the Steering Wheel Point (SWP) in "X" (horizontal) and "Z" (vertical) coordinates.	1.1 Input parameter is available for steering wheel position in X	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 Input parameter is available for steering wheel position in Z	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model allows for selection of seat hydration pack relief in the seat	2.1 Hydration pack relief selection of "yes" in model	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 Hydration pack relief selection of "no" in model	2.2 Representative (Pass) / Non-Representative (Fail)
3	Model allows for selection of either SAE J826 or ISO 5353 for the Human Accommodation Reference Point (HARP) measurement tool	3.1 HARP measurement tool selection of SAE J826 in model	3.1 Representative (Pass) / Non-Representative (Fail)
		3.2 HARP measurement tool selection of ISO 5353 in model	3.2 Representative (Pass) / Non-Representative (Fail)
4	Model allows for input of the population gender mix (e.g. 85% Male : 15% Female)	4.1 Fraction male input option in model	4.1 Representative (Pass) / Non-Representative (Fail)
5	Model allows for selection of ensemble as either PPE or ENC	5.1 Ensemble selection of PPE in model	5.1 Representative (Pass) / Non-Representative (Fail)
		5.2 Ensemble selection of ENC in model	5.2 Representative (Pass) / Non-Representative (Fail)
6	Model allows for a target population input (e.g. 90%)	6.1 Target accommodation input option in model	6.1 Representative (Pass) / Non-Representative (Fail)
7	Model predicts the Steering Wheel Preference Line	7.1 Model outputs a Steering Wheel Preference Line and SWP that adjusts with different inputs	7.1 Representative (Pass) / Non-Representative (Fail)
		7.2 TARDEC CAD model matches the UMTRI spreadsheet	7.2 Representative (Pass) / Non-Representative (Fail)
8	Model predicts a preferred steering wheel placement zone per guidance provided in the UMTRI paper *Preferred Steering Wheel Locations for Fixed-Heel-Point Driver Stations 2016-09-20* (fore/aft) and draft MIL-STD-1472H (side/side)	8.1 Model outputs a steering wheel placement zone that adjusts with different inputs	8.1 Representative (Pass) / Non-Representative (Fail)
		8.2 TARDEC CAD model matches the UMTRI spreadsheet and MIL-STD-1472H	8.2 Representative (Pass) / Non-Representative (Fail)
9	Model predicts the Accelerator Pedal Angle (APA)	9.1 Model outputs an APA that adjusts with different inputs	9.1 Representative (Pass) / Non-Representative (Fail)
		9.2 TARDEC CAD model matches the UMTRI spreadsheet	9.2 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the expected distribution of driver-selected seat positions relative to the accelerator heel point (AHP) based on the SAE J826 and ISO 5353 Seat Index Point (SIP) seat measurement tools	10.1 Model outputs fore/aft and vertical seat track travel window for a given population and gender mix that adjusts with different inputs	10.1 Representative (Pass) / Non-Representative (Fail)
		10.2 TARDEC CAD model matches the UMTRI spreadsheet	10.2 Representative (Pass) / Non-Representative (Fail)

11	Model predicts the expected (dis)accommodation of driver-selected seat positions relative to the accelerator heel point (AHP) if the seat travel is censored	11.1 Model outputs (dis)accommodation value of a censored seat travel that adjusts with model inputs	11.1 Representative (Pass) / Non-Representative (Fail)
		11.2 TARDEC CAD model matches the UMTRI spreadsheet	11.2 Representative (Pass) / Non-Representative (Fail)
12	Model predicts the seat back angle adjustment range	12.1 Model outputs a range of seta back angles measured from vertical and adjusts with different inputs for the population	12.1 Representative (Pass) / Non-Representative (Fail)
		12.2 TARDEC CAD model matches the UMTRI spreadsheet	12.2 Representative (Pass) / Non-Representative (Fail)
13	Model predicts the dimensions and location of the eyellipse with respect to AHP and mean seat travel	13.1 Model outputs a left and right eyellipse for a given population and gender mix that adjusts with different inputs	13.1 Representative (Pass) / Non-Representative (Fail)
		13.2 TARDEC CAD model matches the UMTRI spreadsheet	13.2 Representative (Pass) / Non-Representative (Fail)
14	Model predicts the helmet contour boundary (helmet locations) with respect to the eye location and fitted to the eyellipse	14.1 Model outputs a helmet contour for the given population and gender mix that adjusts with the different inputs	14.1 Representative (Pass) / Non-Representative (Fail)
		14.2 TARDEC CAD model matches the UMTRI spreadsheet	14.2 Representative (Pass) / Non-Representative (Fail)
15	Model predicts the knee contour with leg and thigh segment angles based on location of resting drivers' knees in vehicle	15.1 Model outputs a knee ellipsoid for the given population and gender mix that adjusts with different inputs	15.1 Representative (Pass) / Non-Representative (Fail)
		15.2 TARDEC CAD model matches the UMTRI spreadsheet	15.2 Representative (Pass) / Non-Representative (Fail)
16	Model predicts torso contour with selected ensemble	16.1 Model predicts a torso contour with ensemble for the given population, gender mix, and ensemble configuration that adjusts with different inputs	16.1 Representative (Pass) / Non-Representative (Fail)
		16.2 TARDEC CAD model matches the UMTRI spreadsheet	16.2 Representative (Pass) / Non-Representative (Fail)
17	Model predicts elbow contours based on location of resting drivers' elbows in vehicle	17.1 Model outputs elbow contours for the given population and gender mix that adjusts with different inputs	17.1 Representative (Pass) / Non-Representative (Fail)
		17.2 TARDEC CAD model matches the UMTRI spreadsheet	17.2 Representative (Pass) / Non-Representative (Fail)
18	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD-1472G requirements	18.1 Model outputs a 2" clearance zone from the top of the helmet contour that adjusts with the different inputs	18.1 Representative (Pass) / Non-Representative (Fail)
19	Model provides a clearance zone for the knee, leg and thigh based on MIL-STD-1472H draft recommendations	19.1 Model outputs a 2" clearance zone from the top and front of the knee contour and the front of the leg segment and top of the thigh (in side-view) and adjusts with different inputs	19.1 Representative (Pass) / Non-Representative (Fail)
20	Model provides a clearance zone for the torso boundary, with selected	20.1 Model outputs a 2" clearance zone forward from the torso	20.1 Representative (Pass) / Non-Representative (Fail)

	ensemble, based on MIL-STD-1472H draft recommendations	boundary and adjusts and adjusts with the different inputs	
21	Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472H draft recommendations	21.1 Model output provides a 2" clearance zone laterally for the resting elbow contours	21.1 Representative (Pass)/ Non-Representative (Fail)
22	Model provides direct field of view (primary, secondary, and tertiary zones) based on MIL-STD-1472G and SAE J1050	22.1 Model outputs primary vision zone that adjusts with model inputs	22.1 Representative (Pass) / Non-Representative (Fail)
		22.2 Model outputs secondary vision zone that adjusts with model inputs	22.2 Representative (Pass) /Non-Representative (Fail)
		22.3 Model outputs tertiary vision zone that adjusts with model inputs	22.3 Representative (Pass) /Non-Representative (Fail)
23	Model provides a ground intercept	23.1 Model outputs a line tangent to the bottom of the eyellipse to the ground and adjusts with different user inputs	23.1 Representative (Pass)/ Non-Representative (Fail)

Table 13: Posture Prediction Model Results

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the AHP	1.1 Model outputs the location of the hip with respect to the AHP that matches the UMTRI spreadsheet	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the AHP	2.1 Model outputs the location of the eye with respect to the AHP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

10.2.1 TEST #1 – NUMERICAL RESULTS

Test #1: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	8.900	in	8.900	in	0.000	in
STEERING_WHEEL_Z	30.900	in	30.900	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	33.223	deg	33.223	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-6.587	in	-6.587	in	0.000	in
BOFRP (Z)	4.314	in	4.314	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	25.490	in	25.491	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	18.292	in	18.292	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.222	in	3.223	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	15.449	deg	15.445	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	25.647	deg	25.650	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	23.440	in	23.440	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	44.649	in	44.649	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	26.684	in	26.684	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	47.067	in	47.067	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	6.754	in	6.754	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.582	in	7.582	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	20.939	in	20.939	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.160	in	7.162	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.851	in	6.851	in	0.000	in
KNEE_SHIN_ANGLE	19.273	deg	19.273	deg	0.000	deg
KNEE_THIGH_ANGLE	6.124	deg	6.124	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	19.358	in	19.357	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.595	in	35.595	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	26.589	in	26.589	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.135	in	24.135	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

12

Test #1: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	20.647	in	20.647	in	0.000	in
POSTURE_DHM1_HIP_Z	18.060	in	18.060	in	0.000	in
POSTURE_DHM1_EYE_X	21.622	in	21.622	in	0.000	in
POSTURE_DHM1_EYE_Z	40.128	in	40.128	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	22.769	in	22.769	in	0.000	in
POSTURE_DHM2_HIP_Z	18.169	in	18.169	in	0.000	in
POSTURE_DHM2_EYE_X	22.873	in	22.873	in	0.000	in
POSTURE_DHM2_EYE_Z	41.895	in	41.895	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	24.965	in	24.965	in	0.000	in
POSTURE_DHM3_HIP_Z	18.169	in	18.169	in	0.000	in
POSTURE_DHM3_EYE_X	24.282	in	24.282	in	0.000	in
POSTURE_DHM3_EYE_Z	44.119	in	44.119	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	25.973	in	25.973	in	0.000	in
POSTURE_DHM4_HIP_Z	18.157	in	18.157	in	0.000	in
POSTURE_DHM4_EYE_X	24.938	in	24.938	in	0.000	in
POSTURE_DHM4_EYE_Z	45.397	in	45.397	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	25.216	in	25.216	in	0.000	in
POSTURE_DHM5_HIP_Z	18.151	in	18.151	in	0.000	in
POSTURE_DHM5_EYE_X	24.448	in	24.448	in	0.000	in
POSTURE_DHM5_EYE_Z	46.398	in	46.398	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	27.489	in	27.489	in	0.000	in
POSTURE_DHM6_HIP_Z	18.222	in	18.222	in	0.000	in
POSTURE_DHM6_EYE_X	25.858	in	25.858	in	0.000	in
POSTURE_DHM6_EYE_Z	44.618	in	44.618	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	27.314	in	27.314	in	0.000	in
POSTURE_DHM7_HIP_Z	18.320	in	18.320	in	0.000	in
POSTURE_DHM7_EYE_X	25.635	in	25.635	in	0.000	in
POSTURE_DHM7_EYE_Z	46.357	in	46.357	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

45

10.2.2 TEST #2 – NUMERICAL RESULTS

Test #2: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	14.800	in	14.800	in	0.000	in
STEERING_WHEEL_Z	30.900	in	30.900	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	33.223	deg	33.223	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-6.587	in	-6.587	in	0.000	in
BOFRP (Z)	4.314	in	4.314	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	28.363	in	28.364	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	17.767	in	17.767	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.872	deg	16.868	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.070	deg	27.074	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	26.998	in	26.998	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	44.124	in	44.124	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	30.242	in	30.242	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	46.542	in	46.542	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	9.627	in	9.627	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.085	in	7.085	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.897	in	19.897	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.587	in	7.589	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.350	in	6.350	in	0.000	in
KNEE_SHIN_ANGLE	28.445	deg	28.445	deg	0.000	deg
KNEE_THIGH_ANGLE	6.124	deg	6.124	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_PPE_X	22.231	in	22.231	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.070	in	35.070	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	29.463	in	29.463	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	23.610	in	23.610	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

54

Test #2: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.709	in	23.709	in	0.000	in
POSTURE_DHM1_HIP_Z	17.617	in	17.617	in	0.000	in
POSTURE_DHM1_EYE_X	25.180	in	25.180	in	0.000	in
POSTURE_DHM1_EYE_Z	40.128	in	40.128	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.831	in	25.831	in	0.000	in
POSTURE_DHM2_HIP_Z	17.727	in	17.727	in	0.000	in
POSTURE_DHM2_EYE_X	26.431	in	26.431	in	0.000	in
POSTURE_DHM2_EYE_Z	41.895	in	41.895	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	28.027	in	28.027	in	0.000	in
POSTURE_DHM3_HIP_Z	17.726	in	17.726	in	0.000	in
POSTURE_DHM3_EYE_X	27.839	in	27.839	in	0.000	in
POSTURE_DHM3_EYE_Z	44.119	in	44.119	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	29.035	in	29.035	in	0.000	in
POSTURE_DHM4_HIP_Z	17.715	in	17.715	in	0.000	in
POSTURE_DHM4_EYE_X	28.495	in	28.495	in	0.000	in
POSTURE_DHM4_EYE_Z	45.397	in	45.397	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.278	in	28.278	in	0.000	in
POSTURE_DHM5_HIP_Z	17.709	in	17.709	in	0.000	in
POSTURE_DHM5_EYE_X	28.005	in	28.005	in	0.000	in
POSTURE_DHM5_EYE_Z	46.398	in	46.398	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.551	in	30.551	in	0.000	in
POSTURE_DHM6_HIP_Z	17.780	in	17.780	in	0.000	in
POSTURE_DHM6_EYE_X	29.416	in	29.416	in	0.000	in
POSTURE_DHM6_EYE_Z	44.618	in	44.618	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.376	in	30.376	in	0.000	in
POSTURE_DHM7_HIP_Z	17.877	in	17.877	in	0.000	in
POSTURE_DHM7_EYE_X	29.192	in	29.192	in	0.000	in
POSTURE_DHM7_EYE_Z	46.357	in	46.357	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

83

10.2.3 TEST #3 – NUMERICAL RESULTS

Test #3: Numerical Results, Accommodation

Surrogate Steering Wheel						
	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	28.617	in	28.619	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.146	in	16.146	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	26.716	in	26.716	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.504	in	42.504	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary						
	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.960	in	29.960	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.921	in	44.921	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	10.112	in	10.112	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.611	in	7.613	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.317	in	6.317	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	22.289	in	22.288	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.449	in	33.449	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	29.717	in	29.717	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.989	in	21.989	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

92

Test #3: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

121

10.2.4 TEST #4 – NUMERICAL RESULTS

Test #4: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	11.800	in	11.800	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	27.690	in	27.691	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.279	in	16.279	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.148	deg	16.145	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.346	deg	26.350	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	25.812	in	25.812	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.637	in	42.637	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.056	in	29.056	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	45.054	in	45.055	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	9.382	in	9.382	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.458	in	7.458	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	20.033	in	20.033	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.511	in	7.513	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.452	in	6.452	in	0.000	in
KNEE_SHIN_ANGLE	26.682	deg	26.682	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_PPE_X	21.559	in	21.558	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.583	in	33.583	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	28.790	in	28.790	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	22.123	in	22.123	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

130

Test #4: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	22.881	in	22.881	in	0.000	in
POSTURE_DHM1_HIP_Z	15.992	in	15.992	in	0.000	in
POSTURE_DHM1_EYE_X	24.036	in	24.036	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.003	in	25.003	in	0.000	in
POSTURE_DHM2_HIP_Z	16.102	in	16.102	in	0.000	in
POSTURE_DHM2_EYE_X	25.286	in	25.286	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.199	in	27.199	in	0.000	in
POSTURE_DHM3_HIP_Z	16.101	in	16.101	in	0.000	in
POSTURE_DHM3_EYE_X	26.695	in	26.695	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.207	in	28.207	in	0.000	in
POSTURE_DHM4_HIP_Z	16.090	in	16.090	in	0.000	in
POSTURE_DHM4_EYE_X	27.351	in	27.351	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	27.451	in	27.450	in	0.000	in
POSTURE_DHM5_HIP_Z	16.084	in	16.084	in	0.000	in
POSTURE_DHM5_EYE_X	26.861	in	26.861	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	29.723	in	29.723	in	0.000	in
POSTURE_DHM6_HIP_Z	16.155	in	16.155	in	0.000	in
POSTURE_DHM6_EYE_X	28.271	in	28.272	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	29.548	in	29.548	in	0.000	in
POSTURE_DHM7_HIP_Z	16.252	in	16.252	in	0.000	in
POSTURE_DHM7_EYE_X	28.048	in	28.048	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

159

10.2.5 TEST #5 – NUMERICAL RESULTS

Test #5: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	17.700	in	17.700	in	0.000	in
STEERING_WHEEL_Z	27.000	in	27.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	49.214	deg	49.214	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.144	in	-5.144	in	0.000	in
BOFRP (Z)	5.962	in	5.962	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	31.393	in	31.394	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	13.908	in	13.908	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.222	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	17.572	deg	17.568	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.770	deg	27.774	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	30.025	in	30.025	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	40.266	in	40.266	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	33.269	in	33.269	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	42.683	in	42.683	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	13.535	in	13.535	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.087	in	7.087	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	18.619	in	18.619	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.969	in	7.971	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	5.704	in	5.704	in	0.000	in
KNEE_SHIN_ANGLE	38.906	deg	38.906	deg	0.000	deg
KNEE_THIGH_ANGLE	14.742	deg	14.742	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_PPE_X	25.261	in	25.260	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	31.211	in	31.211	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	32.493	in	32.493	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	19.751	in	19.751	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

168

Test #5: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	26.711	in	26.711	in	0.000	in
POSTURE_DHM1_HIP_Z	13.602	in	13.602	in	0.000	in
POSTURE_DHM1_EYE_X	28.293	in	28.293	in	0.000	in
POSTURE_DHM1_EYE_Z	36.111	in	36.111	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	28.833	in	28.833	in	0.000	in
POSTURE_DHM2_HIP_Z	13.712	in	13.712	in	0.000	in
POSTURE_DHM2_EYE_X	29.543	in	29.543	in	0.000	in
POSTURE_DHM2_EYE_Z	37.878	in	37.878	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	31.029	in	31.028	in	0.000	in
POSTURE_DHM3_HIP_Z	13.711	in	13.711	in	0.000	in
POSTURE_DHM3_EYE_X	30.952	in	30.952	in	0.000	in
POSTURE_DHM3_EYE_Z	40.102	in	40.102	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	32.036	in	32.037	in	0.000	in
POSTURE_DHM4_HIP_Z	13.700	in	13.700	in	0.000	in
POSTURE_DHM4_EYE_X	31.608	in	31.608	in	0.000	in
POSTURE_DHM4_EYE_Z	41.380	in	41.380	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	31.280	in	31.280	in	0.000	in
POSTURE_DHM5_HIP_Z	13.694	in	13.694	in	0.000	in
POSTURE_DHM5_EYE_X	31.118	in	31.118	in	0.000	in
POSTURE_DHM5_EYE_Z	42.381	in	42.381	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	33.553	in	33.553	in	0.000	in
POSTURE_DHM6_HIP_Z	13.765	in	13.765	in	0.000	in
POSTURE_DHM6_EYE_X	32.529	in	32.529	in	0.000	in
POSTURE_DHM6_EYE_Z	40.601	in	40.601	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	33.378	in	33.378	in	0.000	in
POSTURE_DHM7_HIP_Z	13.862	in	13.862	in	0.000	in
POSTURE_DHM7_EYE_X	32.305	in	32.305	in	0.000	in
POSTURE_DHM7_EYE_Z	42.340	in	42.340	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

197

10.2.6 TEST #6 – NUMERICAL RESULTS

Test #6: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	27.602	in	27.603	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.244	in	16.244	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	28.114	in	28.114	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.090	in	42.090	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary

The ACU ensemble does not include a helmet

Knee Boundary	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	10.199	in	10.199	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.611	in	7.613	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.317	in	6.317	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg

Torso Boundary

A torso boundry is not provided when the ACU ensemble is chosen

Elbow Boundary	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	29.627	in	29.627	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.479	in	11.479	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.304	in	21.304	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

206

Test #6: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	26.357	in	26.357	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	27.608	in	27.608	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	29.017	in	29.017	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	29.673	in	29.673	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	29.183	in	29.183	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	30.593	in	30.593	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	30.370	in	30.370	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

230

10.2.7 TEST #7 – NUMERICAL RESULTS

Test #7: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.806	in	1.806	in	0.000	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	30.119	in	30.121	in	0.002	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	15.949	in	15.949	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.515	in	7.506	in	0.008	in
SEAT_POSITION_VERTICAL_TRAVEL	3.698	in	3.695	in	0.004	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	18.133	deg	18.132	deg	0.001	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	30.285	deg	30.287	deg	0.001	deg
Eyellipse						
EYELLIPSE_CENTROID_X	26.593	in	26.594	in	0.001	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.304	in	42.304	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	7.832	in	7.833	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	2.284	in	2.285	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	6.243	in	6.244	in	0.001	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.837	in	29.838	in	0.001	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.721	in	44.721	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	18.284	in	18.285	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.882	in	9.883	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	14.328	in	14.329	in	0.001	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	10.896	in	10.896	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	8.436	in	8.435	in	0.000	in
KNEE_CONTOUR_Y_AXIS_LENGTH	9.529	in	9.527	in	0.002	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.134	in	7.130	in	0.004	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_ENC_Z	16.513	in	16.517	in	0.004	in
TORSO_WEIGHTED_REF_PT_ENC_X	27.720	in	27.720	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	27.276	in	27.276	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	14.707	in	14.707	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.340	in	24.340	in	0.000	in
ELBOW_X_AXIS_LENGTH	8.744	in	8.742	in	0.002	in
ELBOW_Y_AXIS_LENGTH	4.102	in	4.101	in	0.001	in
ELBOW_Z_AXIS_LENGTH	6.486	in	6.488	in	0.001	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.008 inches
0.001 degrees

Values in agreement

239

Test #7: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	24.353	in	24.353	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.822	in	24.822	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	26.475	in	26.475	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.073	in	26.073	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	28.670	in	28.670	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.481	in	27.481	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	29.678	in	29.678	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.137	in	28.137	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.922	in	28.922	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.647	in	27.647	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	31.194	in	31.194	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.058	in	29.058	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	31.020	in	31.020	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.834	in	28.834	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

268

10.2.8 TEST #8 – NUMERICAL RESULTS

Test #8: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in	27.766	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.220	in	16.220	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.045	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	26.271	in	26.271	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.779	in	41.779	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.515	in	29.515	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.196	in	44.196	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.358	in	17.359	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.548	in	13.550	in	0.002	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	9.709	in	9.709	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_PPE_X	21.517	in	21.517	in	0.000	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.076	in	33.076	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	28.690	in	28.690	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.922	in	11.922	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.981	in	21.981	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

277

Test #8: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

306

10.2.9 TEST #9 – NUMERICAL RESULTS

Test #9: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	26.947	in	26.947	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.319	in	16.319	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	27.668	in	27.668	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.365	in	41.365	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary

The ACU ensemble does not include a helmet

Knee Boundary	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	9.796	in	9.796	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg

Torso Boundary

A torso boundry is not provided when the ACU ensemble is chosen

Elbow Boundary	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	28.796	in	28.796	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.048	in	11.048	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.296	in	21.296	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

315

Test #9: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	26.357	in	26.357	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	27.608	in	27.608	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	29.017	in	29.017	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	29.673	in	29.673	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	29.183	in	29.183	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	30.593	in	30.593	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	30.370	in	30.370	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

339

10.2.10 TEST #10 – NUMERICAL RESULTS

Test #10: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in	27.766	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.023	in	16.023	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	19.110	deg	19.107	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	29.308	deg	29.312	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	26.271	in	26.271	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.582	in	41.582	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.515	in	29.515	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	43.999	in	43.999	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.358	in	17.359	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.548	in	13.550	in	0.002	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	9.709	in	9.709	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_ENC_Z	15.983	in	15.983	in	0.000	in
TORSO_WEIGHTED_REF_PT_ENC_X	27.795	in	27.795	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	24.717	in	24.717	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	14.276	in	14.276	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.331	in	24.331	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

348

Test #10: Numerical Results, Manikin Positioning

Small Overall Female	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

377

10.3 APPENDIX C – REFERENCES

Department of Defense. (2008). *Standard Practice – Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulations*. Alexandria, VA. (MIL-STD-3022).

Department of Defense. (2012). *Design Criteria Standard – Human Engineering*. Redstone Arsenal, AL. (MIL-STD-1472G).

Huston II, F., Zielinski, G., and Reed, M. (2016). *Creation of the Driver Fixed Heel Point (FHP) CAD Accommodation Model for Military Ground Vehicle Design*. DTIC Technical Report TR-28004. NDIA Ground Vehicle Systems Engineering and Technology Symposium (GVSETS) Modeling and Simulation, Testing and Validation (MSTV) Mini-Symposium August 2 – 4, Novi, Michigan.

Reed, M. (2016). *Preferred Steering Wheel Locations for Fixed-Heel-Point Driver Stations*. University of Michigan Transportation Research Institute, Ann Arbor, MI

Reed, M. (2016). *Seated Soldier Elbow Clearance Zones*. University of Michigan Transportation Research Institute, Ann Arbor, MI.

Reed, M. (2014). *Seated Soldier Posture Prediction 2014-09-01* [Excel spreadsheet]. University of Michigan Transportation Research Institute, Ann Arbor, MI.

Reed, M. (2017). *Soldier Driver Accommodation Models 2017-05-03* [Excel Spreadsheet]. MI: University of Michigan Transportation Research Institute.

Reed, M., and Ebert, S. (2013). *The Seated Soldier Study: Posture and Body Shape in Vehicle Seats*. Final Report UMTRI-2013-13. University of Michigan Transportation Research Institute, Ann Arbor, MI. https://deepblue.lib.umich.edu/handle/2027.42/109725

SAE Recommended Practice, *SAE J1050 Describing and Measuring the Driver's Field of View*, SAE, 2009.

Zerehsaz, Y., Ebert, S., and Reed, M. (2014). *Development of Accommodation Models for Soldiers in Vehicles-Driver*. Final Report UMTRI-2014-26. University of Michigan Transportation Research Institute, Ann Arbor, MI.
https://deepblue.lib.umich.edu/handle/2027.42/112059

Zielinski, G. and Huston II, F. (2017). *Fixed Heel Point (FHP) Verification and Validation (V and V) Plan*. DTIC Technical Report TR-28822. U.S. Army Tank Automotive Research, Development, and Engineering Center, Warren, MI.

Zielinski, G., Huston II, F., Kozycki, R., Kouba, R., and Wodzinski, C. (2015). *Introduction to Boundary Manikins and Accommodation Models for Military Ground Vehicle Occupant Centric*

Design. DTIC Technical Report TR-26516. U.S. Army Tank Automotive Research, Development, and Engineering Center, Warren, MI.

10.4 APPENDIX D – ACRONYMS

ACH	Advanced Combat Helmet
ACT	Advanced Concepts Team
ACU	Advanced Combat Uniform
AHP	Accelerator Heel Point
AN SUR	Army Anthropometric Survey
APA	Accelerator Plane Angle
ARLHRED	Army Research Laboratory Human Research and Engineering Directorate
CAD	Computer-Aided Design
COTS	Commercial Off-The-Shelf
CSI	Center for System Integration
EMD	Engineering Manufacturing and Development
ENC	Encumbered
ES AP I	Enhanced Small Arms Protective Insert
ESBI	Enhanced Side Ballistic Inserts
FE	Field Element
FEP	Fixed Eye Point
FHP	Fixed Heel Point
FOV	Field-of-View
GVSP	Ground Vehicle Survivability and Protection
HARP	Human Accommodation Reference Point
HFE	Human Factors Engineering
HSI	Human Systems Integration
IOTV	Improved Outer Tactical Vest
JTTS	Joint Tactical Transportation System
MCoE	Maneuver Center of Excellence
MERS	Marine Expeditionary Rifle Squad
MS	Milestone
M&S	Modeling and Simulation
NSRDEC	Natick Soldier Research Development and Engineering Center
OCP	Occupant Centric Platform
OOH	Out-of-Hatch
PPE	Personal Protective Equipment
SIAT	System Engineering, Interoperability, Architecture & Technology
SIP	Seat Index Point
SME	Subject Matter Experts
SWP	Steering Wheel Point
TACOM	Tank Automotive Command
TARDEC	Tank Automotive Research, Development, and Engineering Center
TECD	Technology Capability Demonstration
UMTRI	University of Michigan Transportation Research Institute

10.5 APPENDIX E – DISTRIBUTION LIST

US Army Tank Automotive Research, Development, and Engineering Center (TARDEC):

- Gale L. Zielinski, Mechanical Engineer/Advanced Concepts Team (ACT), RDECOM-TARDEC, Warren, MI 48397-5000, Office: 586-282-5287, E-Mail: gale.l.zielinski.civ@mail.mil
- Frank J. Huston II, Mechanical Engineer/ACT, RDECOM-TARDEC, Warren, MI 48397-5000, Office: 586-282-5657, E-Mail: frank.j.huston.civ@mail.mil
- Russell D. Kouba, Team Leader/ ACT, RDECOM-TARDEC, Warren, MI 48397-5000, Office: 586-282-7806, E-Mail: russell.d.kouba.civ@mail.mil
- Gale M. Litrichin, Principal Seat Engineer – Interior Blast Mitigation Team (IBMT)/Ground Vehicle Survivability and Protection (GVSP), RDECOM-TARDEC, Warren MI 48397-5000, Office: 586-282-0608, E-Mail: gale.m.litrichin.civ@mail.mil
- Eric S. Paternoster, CSI Systems Integration Team, RDECOM-TARDEC, Warren MI 48397-5000, Office: 586-282-0976, E-Mail: eric.s.paternoster2.civ@mail.mil

Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED):

- Richard W. Kozycki, ARL HRED, RDRL-HRM-B, Aberdeen Proving Ground, MD 21005-5425, Office: (410) 278-5880, E-Mail: richard.w.kozycki.civ@mail.mil
- Cheryl A. Burns, ARL HRED, RDRL-HRM-H, Fort Knox, KY 40121, Office: (502) 624-1607, E-Mail: cheryl.a.burns12.civ@mail.mil
- David A. Hullinger, Human Factors Engineer, ARL HRED – TACOM Field Element, RDRL-HRM-CU, Warren, MI 48397-5000, Office: 586-282-8669, E-Mail: david.a.hullinger.civ@mail.mil
- Joseph R. Urda, Human Factors Engineer, ARL HRED – TACOM Field , TACOM Field Element, RDRL-HRM-CU, Warren, MI 48397-5000, Office: (586) 282-5662, E-Mail: joseph.r.urda.civ@mail.mil

US Army Natick Soldier Research, Development, and Engineering Center (NSRDEC):

- Steven Paquette, Anthropology Team Leader, NSRDEC, Natick, MA 01760, Office: (508) 233-5430, E-Mail: steven.p.paquette.civ@mail.mil
- Joseph L. Parham, Research Anthropologist, NSRDEC, Natick, MA 01760, Office: (508) 233-5787, E-Mail: joseph.l.parham2.civ@mail.mil
- Dawn L. Woods, Human Factors Engineer, NSRDEC, Natick, MA 01760, Office: 508-233-5069, E-Mail: dawn.l.woods6.civ@mail.mil

Maneuver Center of Excellence (MCoE):

- Gustave R. Steenborg, Systems Safety Engineer, Mounted Requirements Division Capabilities Development and Integration Directorate MCoE, Fort Benning, GA 31905, Office: (708) 545-0751, E-Mail: gustave.r.steenborg.civ@mail.mil

Marine Expeditionary Rifle Squad (MERS):

- Brian D. Corner, PhD., Research Anthropologist, Systems Engineering, Interoperability, Architectures & Technology (SIAT), Office: 703-432-3231, E-Mail: brian.corner@usmc.mil

Naval Surface Warefare Center – Warfare Systems Department:

- Brian Keeven, Engineer - Human System Integration, Dahlgren, VA 22448, Office: (540) 653-1007, E-Mail: brian.keeven@navy.mil

University of Michigan Transportation Research Institute (UMTRI):

- Matthew P. Reed, PhD., Research Professor and Head Biosciences Group, UMTRI, Ann Arbor, MI 48109-2150, Office: 734-936-1111, E-Mail: mreed@umich.edu

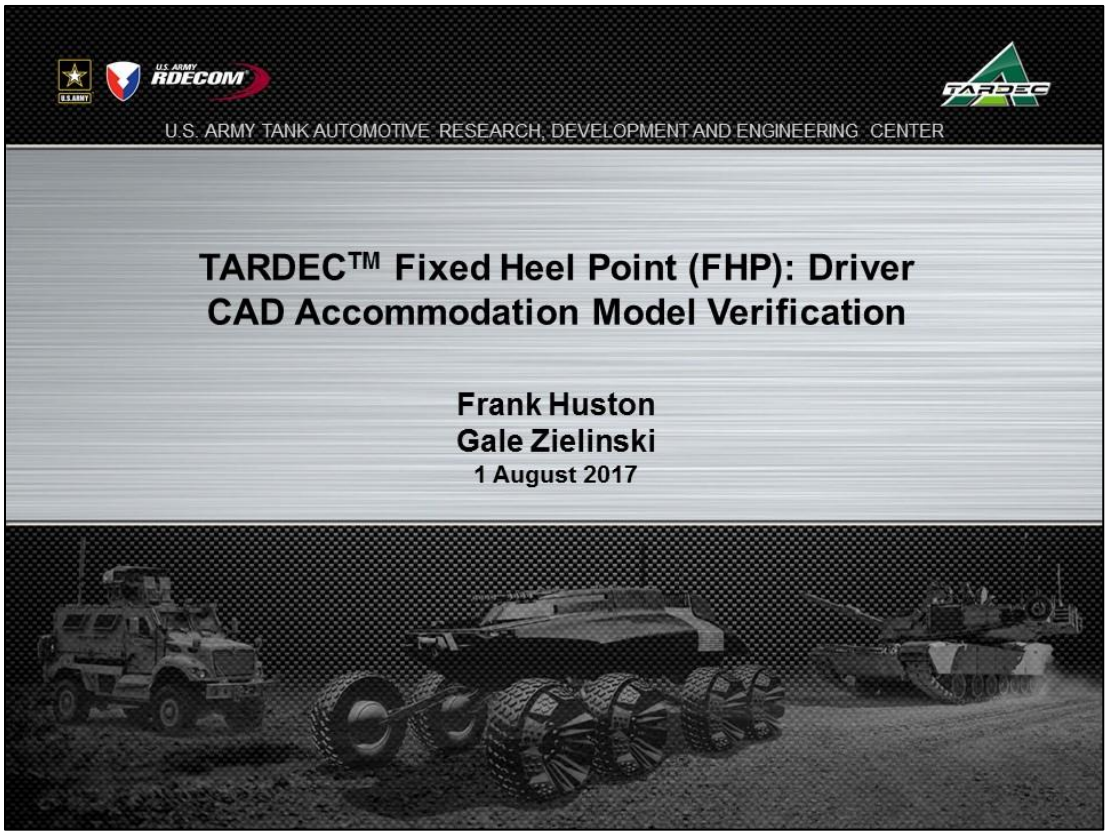
10.6 APPENDIX F – VERIFICATION PLAN

The *Fixed Heel Point Verification and Validation (V and V) Plan – Rev A* (2017) is located in the Defense Technical Information Center (DTIC) database. The reference for the final plan is below:

Zielinski, G. and Huston II, F. (2017). *Fixed Heel Point (FHP) Verification and Validation (V and V) Plan*. DTIC Technical Report TR-28822. Distribution A. U.S. Army Tank Automotive Research, Development, and Engineering Center, Warren, MI.

10.7 APPENDIX G - INITIAL TASK ANALYSIS

Ten different test scenarios were completed for the 1 August 2017 verification event. This section outlines each test scenario and compares TARDEC's CAD results to UMTRI's Microsoft Excel results. The model geometry was adjusted by changing values assigned to the input parameter table in the CAD top assembly and then regenerating the model. This information was provided to all verification invitees prior to the event.



Purpose

Verify the TARDEC™ Fixed Heel Point (FHP): Driver CAD accommodation model

What is verification?

Verification, per the *Department of Defense Standard Practice Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulation* (2008) is defined as follows:

> Verification is the process of determining that a model, simulation, or federation of models and simulations implementations and their associated data accurately represents the developer's conceptual description and specifications.

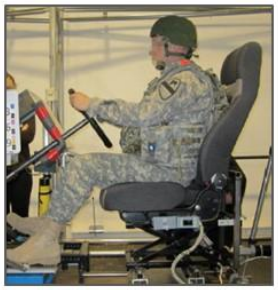
Does the TARDEC Fixed Heel Point (FHP): Driver CAD accommodation model output match the UMTRI accommodation model spread sheet output?

2

Defining In-Vehicle Occupant Positioning Posture Prediction and Accommodation Models

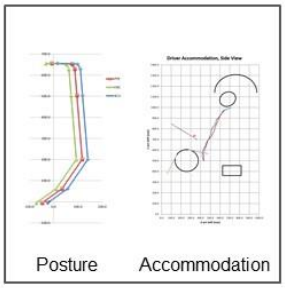
Empirical Soldier data is being used to develop CAD tools that realistically posture and position boundary manikins and predict population body boundaries for crew and squad

- Results, which are repeatable, allow for vehicle design from the occupant outward
- Trades between the vehicle and its occupants are data driven and quantifiable



UMTRI Seated Soldier Study

Soldier preferred posture and positioning, while wearing varying levels of encumbrance, were recorded in driver and squad mockups



UMTRI Posture Prediction

Statistical analysis of the data summarized in Excel-based posture prediction (individuals) and accommodation models (populations)

TARDEC CAD Integration

Morphing parametric CAD models created that respond to user inputs for Soldier population, accommodation level, and vehicle environment

3

CAD Accommodation Tools, A Layered Approach

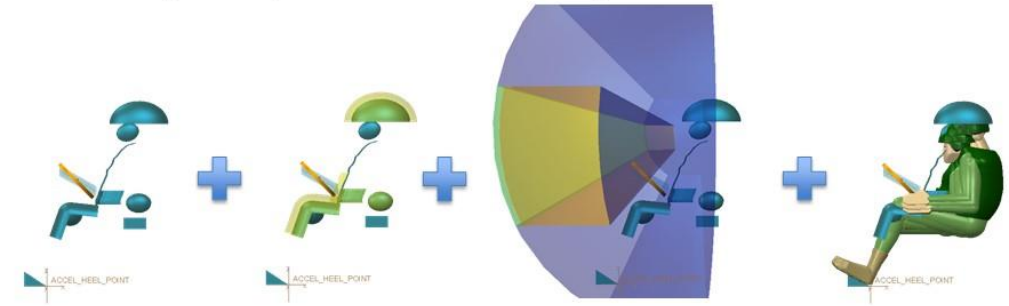
The TARDEC™ FHP: Driver CAD Accommodation Model consists of the following:

Basic Accommodation
Includes both population body boundaries representing the aggregate of all occupant positions in the vehicle environment for the target design population and necessary vehicle adjustment ranges

Clearance (2.0 inches)
Clearance between the target design population and the surrounding vehicle environment

Vision Zones
The direct field of view (divided into primary, secondary, and tertiary zones) using a combination of vertical and horizontal visual fields from MIL-STD-1472 and SAE J1050

Boundary Manikins
Positioned boundary manikins provide another reference for design



Basic Accommodation | Clearance (2.0 inches) | Vision Zones | Boundary Manikins

4

What is the Scope of the Verification?

The TARDEC™ Fixed Heel Point (FHP): Driver CAD accommodation model will be audited to determine the following, which is based on Soldier data and SME guidance:

1) Determine if the accommodation boundaries match when using either the TARDEC CAD model or the UMTRI Microsoft Excel spreadsheet *Soldier Driver Accommodation Models 2017-06-08*
2) Determine if the steering wheel placement zone matches the guidance provided in the UMTRI paper *Preferred Steering Wheel Locations for Fixed-Heel-Point Driver Stations 2016-09-20*
3) Determine if the clearance zones (helmet, abdominal, knees, legs, and shins) match what Subject Matter Experts (SME) interpreted using MIL-STD-1472G
4) Determine if direct field of view (primary, secondary, and tertiary) matches what SMEs interpreted using MIL-STD-1472G and SAE J1050
5) Determine if ground intercept can be calculated using the model based on MIL-STD-1472G ground intercept requirement
6) Determine if the hip and eye point of the CAD boundary manikins match the UMTRI Microsoft Excel spreadsheet *Seated Soldier Posture Prediction 2014-09-01*

5

Acceptability Criteria

Inputs

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for input of the Steering Wheel Point (SWP) in "X" (horizontal) and "Z" (vertical) coordinates.	1.1 Input parameter is available for steering wheel position in X	1.1 Representative (Pass)/ Non-Representative (Fail)
		1.2 Input parameter is available for steering wheel position in Z	1.2 Representative (Pass)/ Non-Representative (Fail)
2	Model allows for selection of ensemble as either PPE or ENC	2.1 Ensemble selection of PPE in model	2.1 Representative (Pass)/ Non-Representative (Fail)
		2.2 Ensemble selection of ENC in model	2.2 Representative (Pass)/ Non-Representative (Fail)
3	Model allows for input of seat hydration pack relief	3.1 Hydration pack relief selection of "yes" in model	3.1 Representative (Pass)/ Non-Representative (Fail)
		3.2 Hydration pack relief selection of "no" in model	3.2 Representative (Pass)/ Non-Representative (Fail)
4	Model allows for selection of either SAE J826 or ISO 5353 for the Human Accommodation Reference Point (HARP) measurement tool	4.1 HARP measurement tool selection of SAE J826 in model	4.1 Representative (Pass) / Non-Representative (Fail)
		4.2 HARP measurement tool selection of ISO 5353 in model	4.2 Representative (Pass) / Non-Representative (Fail)
5	Model allows for input of population gender mix (e.g. 85% Male : 15% Female)	5.1 Fraction male input option in model	5.1 Representative (Pass) / Non-Representative (Fail)
6	Model allows for input of target population (e.g. 90%)	6.1 Target accommodation input option in model	6.1 Representative (Pass) / Non-Representative (Fail)

Outputs

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
7	Model predicts the Steering Wheel Preference Line	7.1 Model outputs a Steering Wheel	7.1 Representative (Pass)/
8	12 Model predicts the knee contour with leg and thigh segment	12.1 Model outputs a knee ellipsoid	12.1 Representative (Pass)/
9	13 18 Model provides a clearance zone for the thigh to steering wheel based on MIL-STD-1472H draft recommendations	18.1 Model outputs a 2" clearance zone from the top of the thigh to the bottom of the steering wheel as measured in side-view	18.1 Representative (Pass)/ Non-Representative (Fail)
10	14 19 Model provides a clearance zone for the leg segment to the Instrument Panel (IP) or other surfaces based on MIL-STD-1472H draft recommendations	19.1 Model output provides a 2" clearance zone from the top and front of the knee contour and the front of the leg segment	19.1 Representative (Pass)/ Non-Representative (Fail)
11	15 20 Model provides a lateral clearance zone for the elbow contours based on MIL-STD-1472H draft recommendations	20.1 Model output provides a 2" clearance zone laterally for the resting elbow contours	20.1 Representative (Pass)/ Non-Representative (Fail)
	21 Model provides direct field of view (primary, secondary, and tertiary zones) based on MIL-STD-1472G and SAE J1050	21.1 Model outputs primary vision zone that adjusts with model inputs	21.1 Representative (Pass)/ Non-Representative (Fail)
		21.2 Model outputs secondary vision zone that adjusts with model inputs	21.2 Representative (Pass)/ Non-Representative (Fail)
		21.3 Model outputs tertiary vision zone that adjusts with model inputs	21.3 Representative (Pass)/ Non-Representative (Fail)
16	22 Model depict a best-case ground intercept	22.1 Model outputs a best case ground intercept with input of...	22.1 Representative (Pass) / Non-Representative (Fail)
17	23 Model predicts the expected (dis)accommodation of driver-selected seat positions relative to the accelerator heel point (AHP) if the seat travel is censored	23.1 Model outputs (dis)accommodation value of a censored seat travel that adjusts with model inputs	23.1 Representative (Pass) / Non-Representative (Fail)
		23.2 TARDEC CAD model matches the UMTRI spreadsheet	23.2 Representative (Pass) / Non-Representative (Fail)

Boundary Manikin Placement

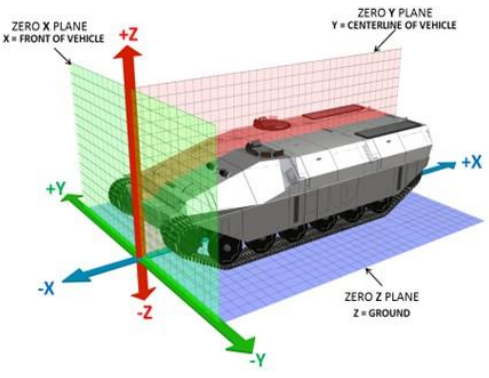
#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the AHP	1.1 Model outputs the location of the hip with respect to the AHP that matches the UMTRI spreadsheet	1.1 Representative (Pass)/ Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass)/ Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the AHP	2.1 Model outputs the location of the eye with respect to the AHP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

6

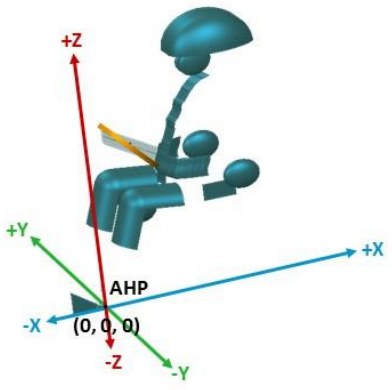
Axis System Review

Vehicles are designed in CAD with respect to a global axis system, as described below
- X-Plane: vertical plane through the front edge of the bumper
- Y-Plane: vertical plane through the centerline of the vehicle
- Z-Plane: horizontal plane through the bottom of the tires/track (ground)

Subsystems within the vehicle are positioned using local axis systems. The TARDEC FHP: Driver model has an axis system located at its origin (0, 0, 0), the Accelerator Heel Point (AHP).



Vehicle Axis System



TARDEC FHP: Driver Axis System

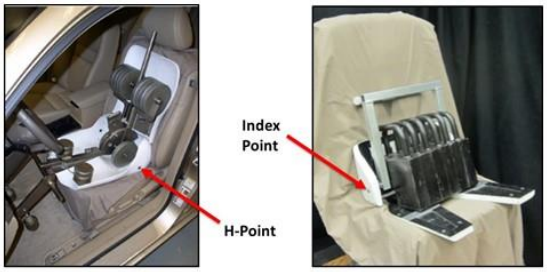
7

Model Inputs – Vehicle Description

Steering Wheel Point (SWP)
The effective center of the steering wheel, located at the intersection between the axis of rotation of the wheel and a plane lying on the driver side of the wheel. The SWP is reported in horizontal and vertical components with respect to the AHP.

Hydration Pack Relief Availability
Indicates the presence of an opening in the seat back that fully accommodates a donned hydration pack, such that the occupant's position in the seat would be the same with or without the hydration pack.

Human Accommodation Reference Point (HARP) Measurement Tool
HARP is a seat reference from which sitter hip locations and other aspects of posture can be calculated. Both the SAE J826 H-point manikin and the ISO 5353 SIP Tool can be used.



SAE J826 H-point Manikin ISO 5353 SIP Tool

8

Model Inputs – Target Design Population

Fraction Male
The expected percentage of males in the defined target design population.

Ensemble
The clothing and equipment that will be worn. The following ensembles are available in the model:

- Personal Protective Equipment (PPE)
  PPE includes the Advanced Combat Uniform (ACU), Improved Outer Tactical Vest (IOTV) and Advanced Combat Helmet (ACH)
- Encumbered (ENC)
  ENC includes all clothing and equipment in PPE plus a rifleman equipment kit as defined in UMTRI-2013-13

Personal Protective Equipment (PPE)

Encumbered (ENC)

Target Accommodation
The percentage of the defined target design population to be accommodated. Those not accommodated are evenly split between the smaller and larger extremes of the population. In MIL-STD-1472G, the accommodation target has been set at the central 90%.

9

Test Matrix

Test #	Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
				X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
1	90%	90%	PPE	8.9	30.9	No	SAE J826
2	90%	90%	PPE	**14.8**	30.9	No	SAE J826
3	90%	90%	PPE	**13.3**	**29.0**	No	**ISO 5353**
4	90%	90%	PPE	**11.8**	29.0	No	**SAE J826**
5	90%	90%	PPE	**17.7**	**27.0**	No	SAE J826
6	90%	90%	**ACU**	**13.3**	**29.0**	No	SAE J826
7	**95%**	90%	**ENC**	13.3	29.0	No	SAE J826
8	**90%**	**50%**	**PPE**	13.3	29.0	No	SAE J826
9	90%	50%	**ACU**	13.3	29.0	No	SAE J826
10	90%	50%	**ENC**	13.3	29.0	**Yes**	SAE J826

Note: Highlighted values differ from the previous test

Tests #1-6 primarily explore the effect of varying the Steering Wheel Point (SWP)
- Geometry and position for the Steering Wheel Preference Line and Steering Wheel Zone are constant
- Geometry for Seat Track Travel and composite body boundaries (except knees) is constant, but position varies
- Knee Boundary geometry and position are unique for each test to reflect changing shin and thigh angles
- Changing the HARP measurement tool only affects the position of Seat Track Travel

Test #7 primarily explores the effect of varying Target Accommodation
- Geometry for Seat Track Travel and composite body boundaries increase in volume with increased Target Accommodation

Tests #8-10 primarily explore the effects of using a different gender mix (Fraction Male) and varying the Ensemble
- Geometry for Seat Track Travel and composite body boundaries decrease in volume with a smaller proportion of males
- Position for Seat Track Travel and composite body boundaries vary with the chosen Ensemble

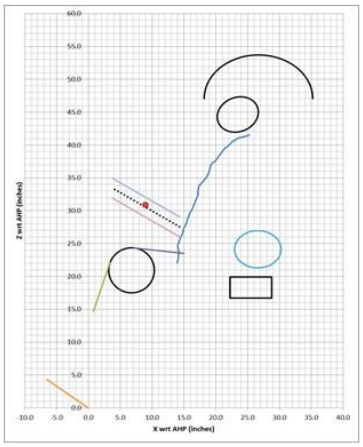
10

10.7.1 TEST #1 – BASELINE COMPARISON

Test #1: Baseline Comparison

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	8.9	30.9	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

11

Test #1: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	8.900	in	8.900	in	0.000	in
STEERING_WHEEL_Z	30.900	in	30.900	in	0.000	in
Steering Wheel Preference Line	**UMTRI Value**		**TARDEC Value**		**Difference**	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone	**UMTRI Value**		**TARDEC Value**		**Difference**	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)	**UMTRI Value**		**TARDEC Value**		**Difference**	
ACCEL_PEDAL_PLANE_ANG	33.223	deg	33.223	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-6.587	in	-6.587	in	0.000	in
BOFRP (Z)	4.314	in	4.314	in	0.000	in
Seat Track Travel Range	**UMTRI Value**		**TARDEC Value**		**Difference**	
SEAT_POSITION_CTR_OF_TRAVEL_X	25.490	in	25.491	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	18.292	in	18.292	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.222	in	3.223	in	0.001	in
Seat Back Angle	**UMTRI Value**		**TARDEC Value**		**Difference**	
SEAT_BACK_ANGLE_LOWER_QUANTILE	15.449	deg	15.445	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	25.647	deg	25.650	deg	0.004	deg
Eyellipse	**UMTRI Value**		**TARDEC Value**		**Difference**	
EYELLIPSE_CENTROID_X	23.440	in	23.440	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	44.649	in	44.649	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	26.684	in	26.684	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	47.067	in	47.067	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
KNEE_CONTOUR_WEIGHTED_CENT_X	6.754	in	6.754	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.582	in	7.582	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	20.939	in	20.939	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.160	in	7.162	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.851	in	6.851	in	0.000	in
KNEE_SHIN_ANGLE	19.273	deg	19.273	deg	0.000	deg
KNEE_THIGH_ANGLE	6.124	deg	6.124	deg	0.000	deg
Torso Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
TORSO_WEIGHTED_REF_PT_PPE_X	19.358	in	19.357	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.595	in	35.595	in	0.000	in
Elbow Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
ELBOW_WEIGHTED_CENT_X	26.589	in	26.589	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.135	in	24.135	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

12

Test #1: Surrogate Steering Wheel

A surrogate steering wheel is automatically positioned at the Steering Wheel Point (SWP). The geometry mimics the steering wheel used in the *Seated Soldier Study* driver mockup. The wheel has a 350 mm (13.78 in.) diameter and is angled at 45° from vertical.

Usage

The surrogate steering wheel is provided for situations in which actual steering wheel geometry is not available.

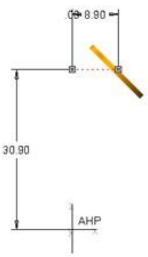
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	8.900	30.900

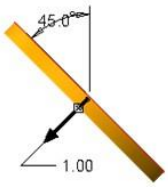
TARDEC CAD Model Calculations

STEERING_WHEEL_X	8.900	in
STEERING_WHEEL_Z	30.900	in

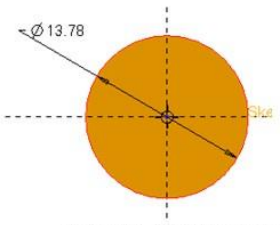
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

Side View **Steering Wheel Geometry**

13

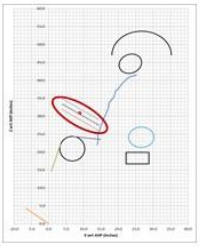
Test #1: Steering Wheel Preference Line

The steering wheel preference line depicts the preferred range of SWPs for the target driver population.

Usage
The SWP should be adjusted to lie on or near this line.

UMTRI Spreadsheet Calculations

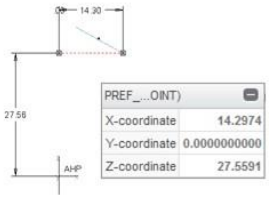
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



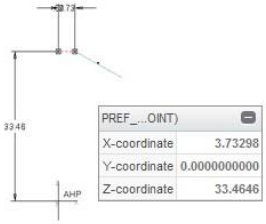
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



Preference Line Endpoint, Max

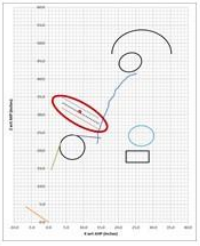
Test #1: Steering Wheel Preference Zone

The steering wheel preference zone depicts an acceptable range, beyond the steering wheel preference line, for positioning the SWP with respect to the target design population.

Usage
The SWP should be located within the steering wheel preference zone.

UMTRI Spreadsheet Calculations

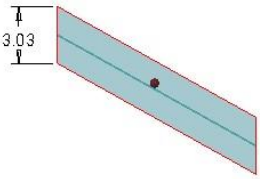
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



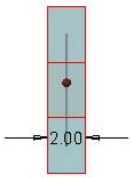
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

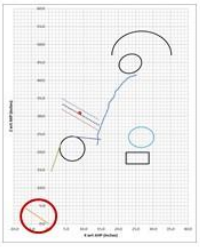
*Given value, not calculated

Test #1: Accelerator Plane Angle (APA)

The APA, calculated from the horizontal component of the SWP, is the theoretical angle at which a boot (with the heel positioned at the AHP) would contact the surface of the undeflected accelerator pedal.

Usage

The APA, along with a 200 mm (7.87 in.) segment, is used to determine the position and orientation of the accelerator pedal. The segment represents the length of a boot from the AHP to the contact point on the accelerator pedal.



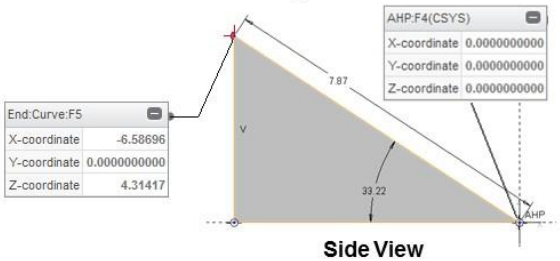
UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA)	33.223 deg	
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-6.587	4.314

TARDEC CAD Model Calculations*

ACCEL_PEDAL_PLANE_ANG	33.223	deg

TARDEC CAD Model Geometry



Side View

*Neither the Origin nor the BOFRP (the endpoints of the oriented boot segment) are calculated in CAD because they are not used to construct the geometry. Instead, a 200 mm segment, oriented to the calculated APA, is anchored to the AHP.

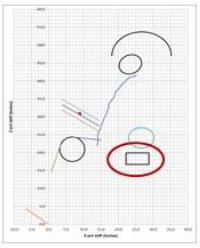
16

Test #1: Seat Track Travel Range

The seat track travel range represents the amount of seat track adjustment, located with respect to the AHP, needed to position individuals from the target design population to reach vehicle controls. The range is reported in terms of the chosen HARP measurement tool.

Usage

Seats should be positioned in the vehicle environment such that the seat track travel window associated with the seat completely encompasses the seat track travel range calculated by the model.



UMTRI Spreadsheet Calculations

Center of Travel (X)	25.490	in
Center of Travel (Z)	18.292	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.222	in

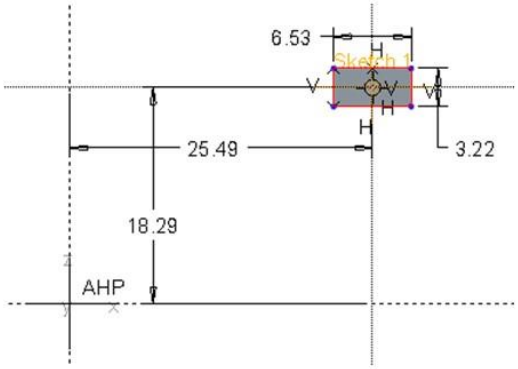
TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	25.491	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	18.292	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in

17

Test #1: Seat Track Travel Range (cont.)

TARDEC CAD Model Geometry
The seat track travel range is represented in both the model geometry and annotated output.



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 8.9 in.
Steering Wheel Point, Z (wrt AHP): 30.9 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 25.5 in., Z = 18.3 in.)

Seat Back Angle (wrt vertical): 15.4° to 25.7°

Warnings
-- Manikins with upper legs less than 5 deg above horiz:
#1 #2

18

Test #1 Bonus Feature: Censored Seat Track

In practice, it may not always be possible to position a seat so that its seat track travel completely encompasses the calculated seat track travel range. Instances of reduced seat track travel (censoring) can be quantified.

Usage
The boundaries of the recommended seat track travel are modified to match what the seat hardware is capable of providing (given the seat's location in vehicle) so that the model can calculate a corrected level of seating accommodation.

TARDEC CAD Model Inputs
- Consider Censored Seating(Yes No)
- Seat Travel Reduction Front
- Seat Travel Reduction Rear
- Seat Travel Reduction Top
- Seat Travel Reduction Bottom

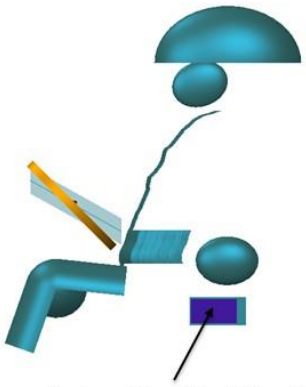
TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Censored)
Fore-aft travel: 5.3 in.
Vertical travel: 2.8 in.
Centered, via SAE J826, @ (X = 25.1 in., Z = 18.3 in.)

Seat Track Travel Disaccommodation, Total
Front: 3.3 % Top: 4.4 %
Rear: 9.2 % Bottom: 4.4 %

Accommodation (Censored): 79.8 %

Warnings
-- Accommodation geometry and manikin positions are not recalculated with censoring



Reduced Seat Track Travel

19

Test #1: Seat Back Angle

The accommodation model assumes that the driver's seat also includes seat back angle adjustment. A range of seat back angles, measured from vertical, is calculated for the target design population.

Usage
Along with seat track travel range, the seat back angle adjustment range should be considered when selecting vehicle seating.

UMTRI Spreadsheet Calculations

Front of Range	15.449 deg
Rear of Range	25.647 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	15.445	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	25.650	deg

TARDEC CAD Model Geometry
Seat back angle, though not represented geometrically, is reported in the annotated model output.

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 25.5 in., Z = 18.3 in.)

Seat Back Angle (wrt vertical): 15.4^{o} to 25.7^{o}

Warnings
-- Manikins with upper legs less than 5 deg above horiz:
#1 #2

20

Test #1: Eyellipse

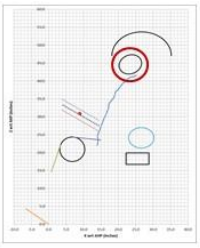
The eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of driver eye locations in the vehicle.

Usage
The eyellipse is used to conduct vision analyses for the target design population.

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	23.440	1.280*	44.649
Left	23.440	-1.280*	44.649

Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in



TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		23.440	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		44.649	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

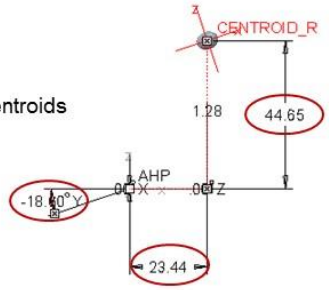
*Given value, not calculated

21

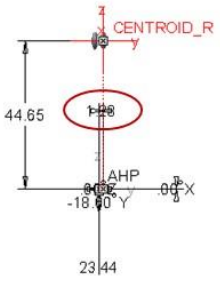
Test #1: Eyellipse (cont.)

TARDEC CAD Model Geometry

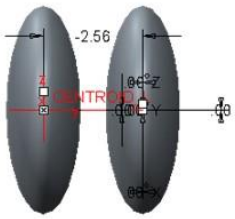
Centroids



Side View

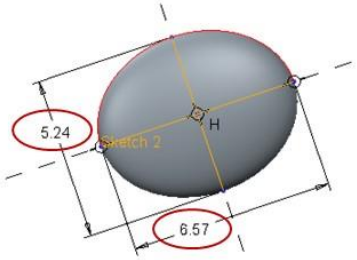


Rear View

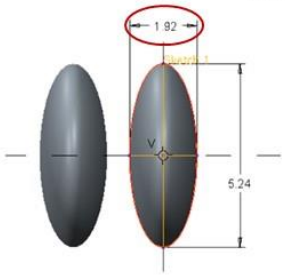


Rear View

Axis Lengths



Side View



Rear View (Rotated)

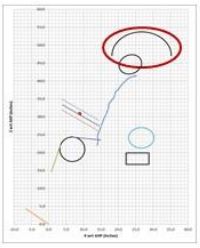
22

Test #1: Helmet Boundary

The helmet boundary depicts the distribution of helmet locations for the target design population. The Advanced Combat Helmet (ACH) was used.

Usage

The helmet boundary is used as reference for providing clearance to surrounding components such as the ceiling.



UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	26.684	2.185*	47.067
Left	26.684	-2.185*	47.067

Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.045	in
Axis Length (Z)	→	13.292	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.292	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		26.684	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		47.067	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.048	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.296	in

$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

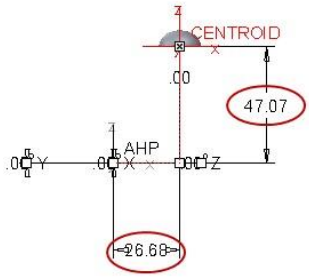
*Given value, not calculated

23

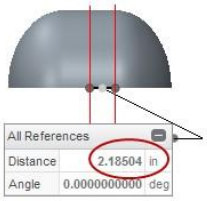
Test #1: Helmet Boundary (cont.)

TARDEC CAD Model Result

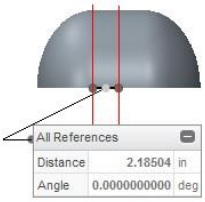
Centroids



Side View

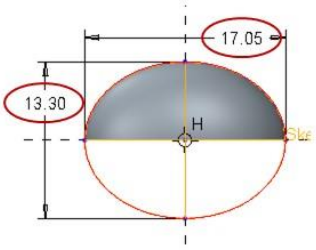


Rear View

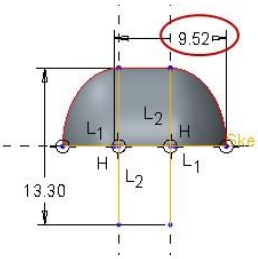


Rear View

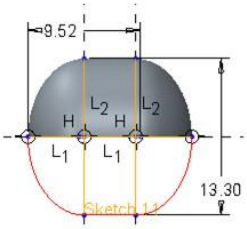
Axis Lengths



Side View



Rear View



Rear View

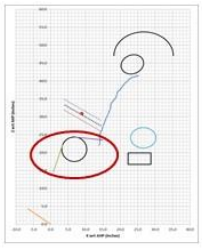
24

Test #1: Knee Boundary

The knee boundary depicts the top, forward, and lateral distribution of resting knee locations for the target design population. Segments of the thigh and shin are also provided.

Usage

The knee boundary is used as reference for providing clearance to surrounding components such as the instrument panel, steering wheel, door trim, and center console.



UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	6.754	7.582	20.939
Left	6.754	-7.582	20.939

Side View of Knee Contours (X, Z)		
Axis Length (X)	7.160	in
Axis Length (Z)	6.851	in
Rear View of Knee Contours (Y, Z)		
Axis Length (Y)	8.671	in
Axis Length (Z)	6.851	in
Leg Segment Angle wrt Vertical	19.273	deg
Thigh Segment Angle wrt Horizontal	6.124	deg

TARDEC CAD Model Calculations

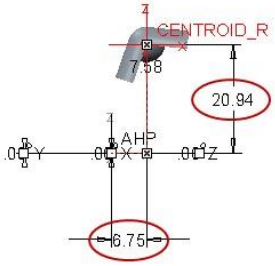
KNEE_CONTOUR_WEIGHTED_CENT_X	6.754	in
KNEE_CONTOUR_WEIGHTED_CENT_Y	7.582	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	20.939	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.162	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.851	in
KNEE_SHIN_ANGLE	19.273	deg
KNEE_THIGH_ANGLE	6.124	deg

25

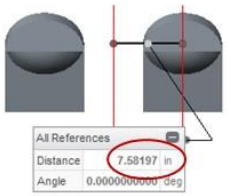
Test #1: Knee Boundary (cont.)

TARDEC CAD Model Result

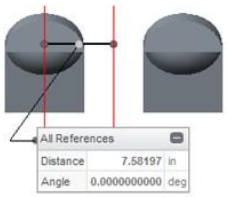
Centroids



Side View

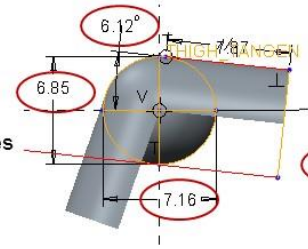


Rear View

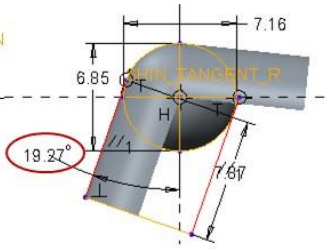


Rear View

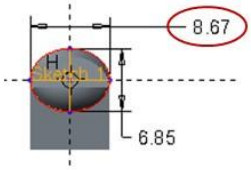
Axis Lengths
Shin/Thigh Angles



Side View



Side View



Rear View

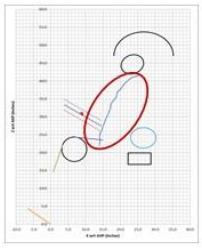
26

Test #1: Torso Boundary (PPE)

The torso boundary depicts the distribution of driver torsos, including the effects of ensemble, for the target design population. The geometry, which is static, is repositioned based on the SWP, population, and ensemble.

Usage

The torso boundary is used as reference for providing clearance to surrounding components such as the steering wheel, door trim, and center console.



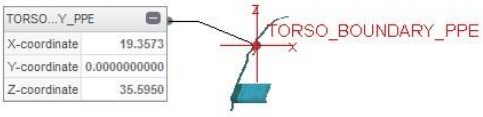
UMTRI Spreadsheet Calculations

Mean Reference Point	X (in)	Z (in)
PPE	19.358	35.595
ENC	12.392	30.063

TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	19.357	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.595	in

TARDEC CAD Model Geometry



Side View

27

Test #1: Elbow Boundary

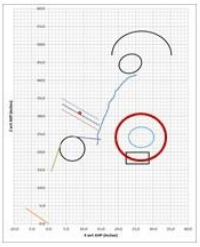
The elbow boundary depicts the distribution of resting elbow locations for the target design population.

Usage

The elbow boundary is used as reference for providing clearance to surrounding components such as door trim and the center console.

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	26.589	12.353	24.135
Left	26.589	-12.353	24.135



Side View of Elbow Contours (X, Z)
Axis Length (X) → 7.303 in
Axis Length (Z) → 5.665 in

Rear View of Elbow Contours (Y, Z)
Axis Length (Y) → 3.424 in
Axis Length (Z) → 5.665 in

TARDEC CAD Model Calculations

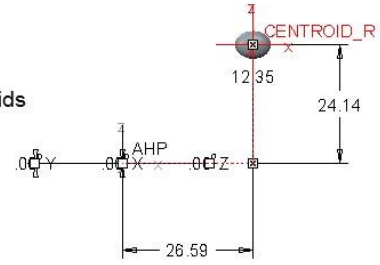
ELBOW_WEIGHTED_CENT_X	26.589	in
ELBOW_WEIGHTED_CENT_Y	12.353	in
ELBOW_WEIGHTED_CENT_Z	24.135	in
ELBOW_X_AXIS_LENGTH	7.305	in
ELBOW_Y_AXIS_LENGTH	3.425	in
ELBOW_Z_AXIS_LENGTH	5.668	in

28

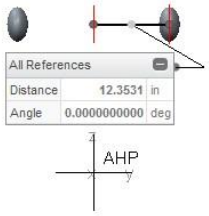
Test #1: Elbow Boundary (cont.)

TARDEC CAD Model Result

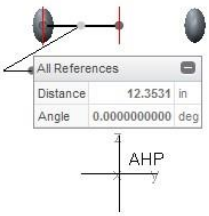
Centroids



Side View

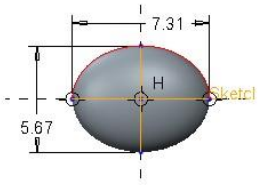


Rear View

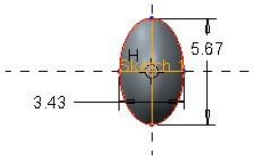


Rear View

Axis Lengths



Side View



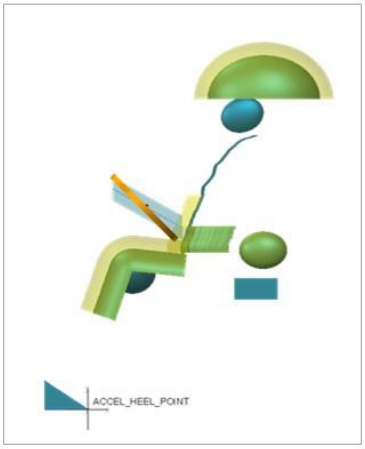
Rear View

29

Test #1: Baseline Comparison

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	8.9	30.9	No	SAE J826

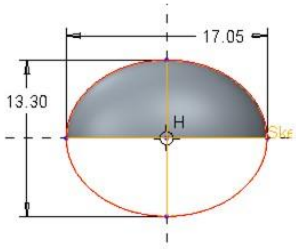
Clearance (2.0 inches), Shown in Yellow

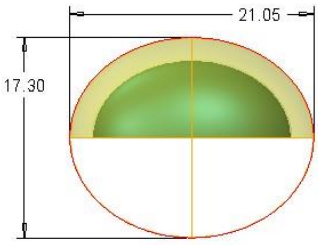


TARDEC CAD Model

30

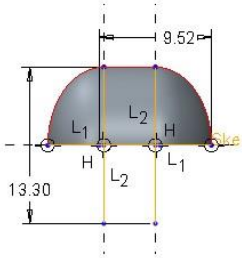
Test #1: Clearance, Helmet Boundary

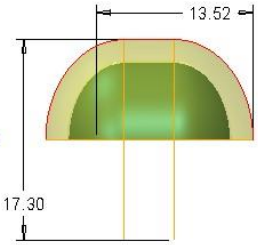


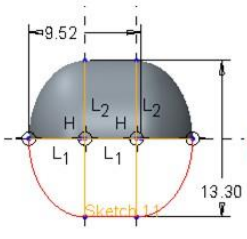


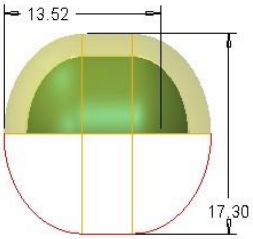
$$Sample\ Calculation: \frac{1}{2}\,(21.048\,in. - 17.048\,in.) = 2.000\,in.\,clearance$$

Side View





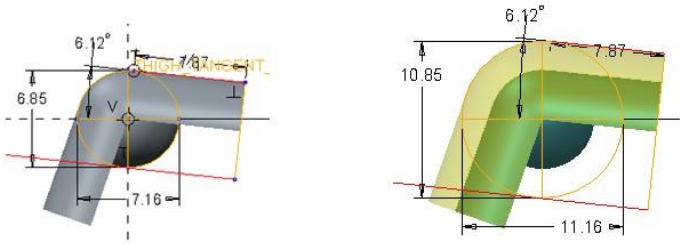




Rear View

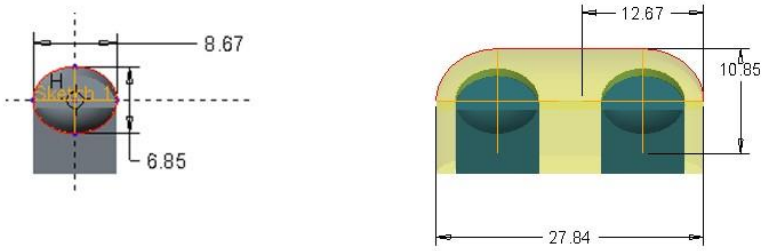
31

Test #1: Clearance, Knee Boundary



Sample Calculation: $\frac{1}{2}(10.851\,in. - 6.851\,in.) = 2.000\,in.\,clearance$

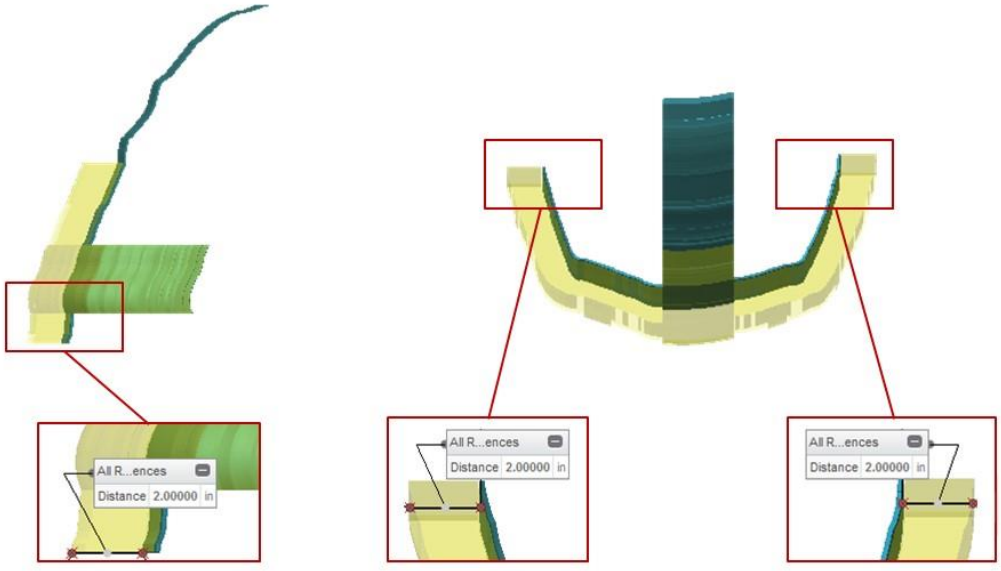
Side View



Rear View

32

Test #1: Clearance, Torso Boundary (PPE)



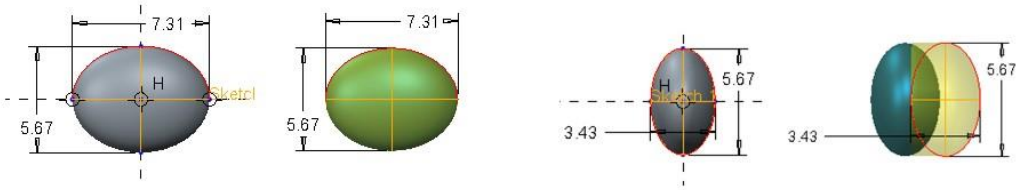
Side View **Top View**

33

Test #1: Clearance, Elbow Boundary

Sample Calculation: $14.353\ in. - 12.353\ in. = \ 2.000\ in.\ clearance$

Rear View



Side View **Rear View**

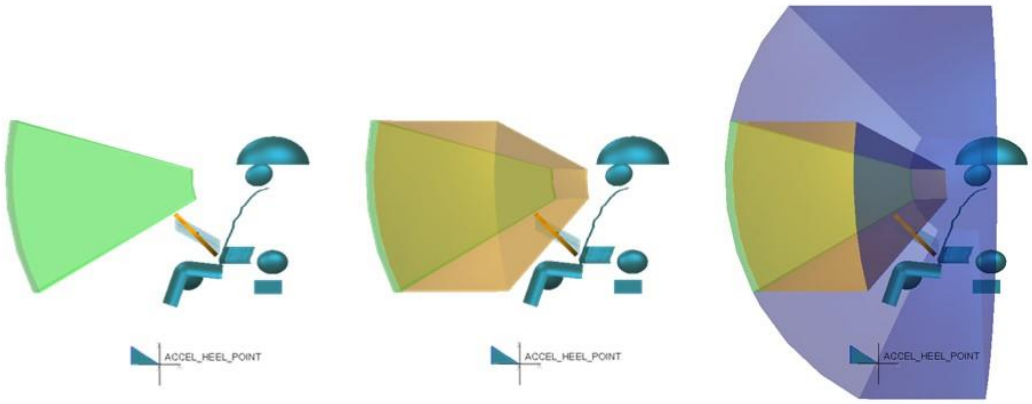
34

Test #1: Baseline Comparison

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	8.9	30.9	No	SAE J826

Vision Zones

Vison zones are constructed geometrically; no calculations are involved.



Primary Zone Secondary Zone Tertiary Zone

35

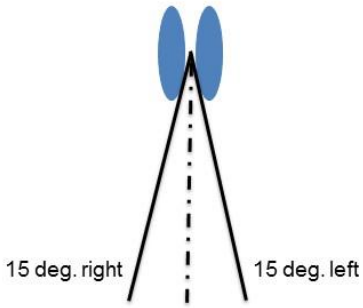
Test #1: Primary Vision Zone

The primary vision zone indicates a space viewable by all occupants using a minimum of easy rotation from at least one eye (ambinocular vision).

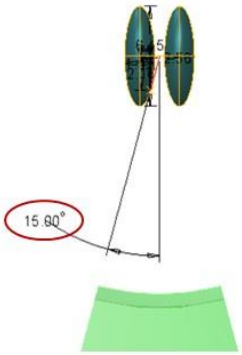
Usage
Warning lights and displays are to be placed in the primary vision zone.

Zone Construction
Combining the limits MIL-STD-1472 G and SAE J1050, easy eye rotation is defined laterally as 15 degrees side-to-side from the occupant's centerline and vertically as +15/-30 degrees from horizontal.

The effective viewing distance shall not be less than 13 inches.



Top View

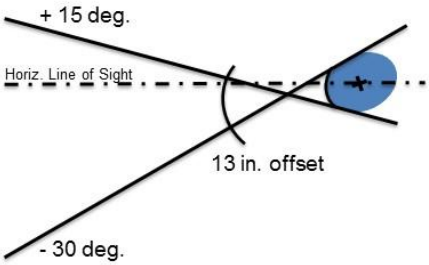


Intent

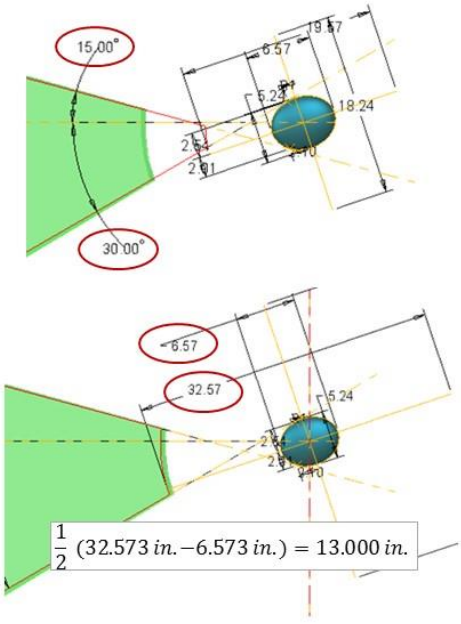
CAD Implementation

36

Test #1: Primary Vision Zone (cont.)



Side View



Intent

CAD Implementation

37

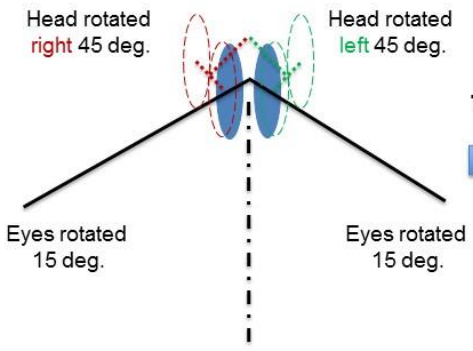
Test #1: Secondary Vision Zone

The secondary vision zone indicates a space viewable by all occupants using both "easy" eye and "easy" head rotation.

Usage
The secondary vision zone is suitable for cautions and alerts not able to be placed in the primary vision zone.

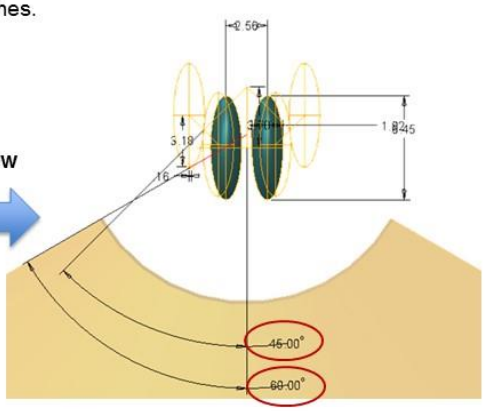
Zone Construction
Combining the limits MIL-STD-1472 G and SAE J1050, easy eye rotation and easy head turn is defined laterally as 60 degrees side-to-side from the occupant's centerline (15 degrees eye rotation + 45 degrees head rotation) and vertically as +15/-30 degrees from horizontal (eye rotation only).

The effective viewing distance shall not be less than 13 inches.



Intent

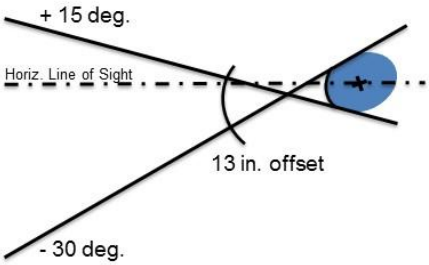
Top View



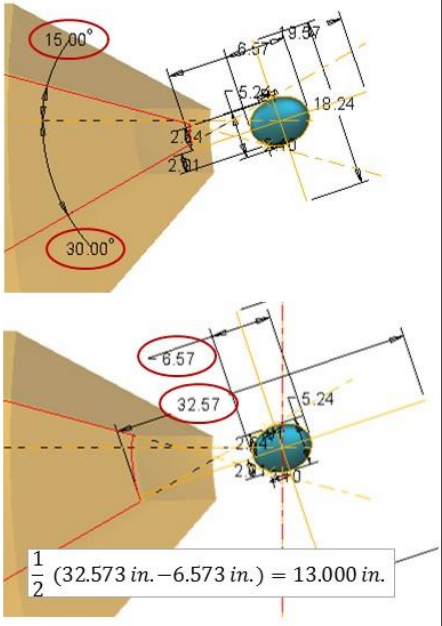
CAD Implementation

38

Test #1: Secondary Vision Zone (cont.)



Side View



Intent

CAD Implementation

39

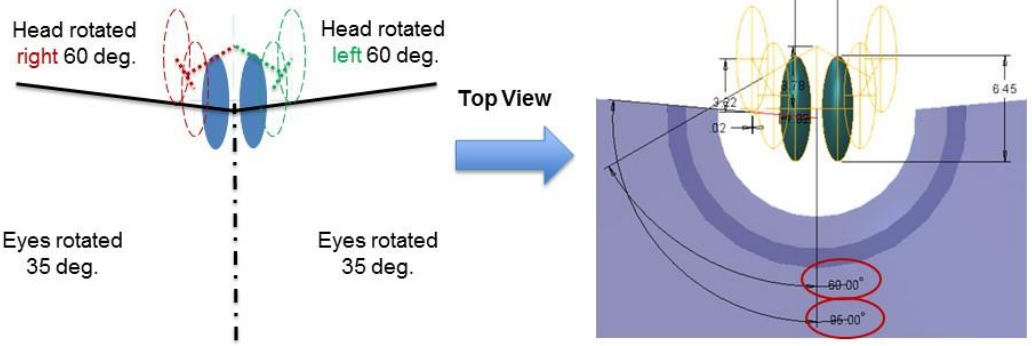
Test #1: Tertiary Vision Zone

The tertiary vision zone indicates a space viewable by all occupants using both maximum eye and maximum head rotation.

Usage
The tertiary vision zone should only be used to place equipment needed for initial setup but not requiring attention while driving.

Zone Construction
Combining the limits MIL-STD-1472 G and SAE J1050, maximum eye rotation and maximum head turn is defined laterally as 95 degrees side-to-side from the occupant's centerline (35 degrees eye + 60 degrees head) and vertically as +45 degrees/-65 degrees from horizontal (eye rotation only).

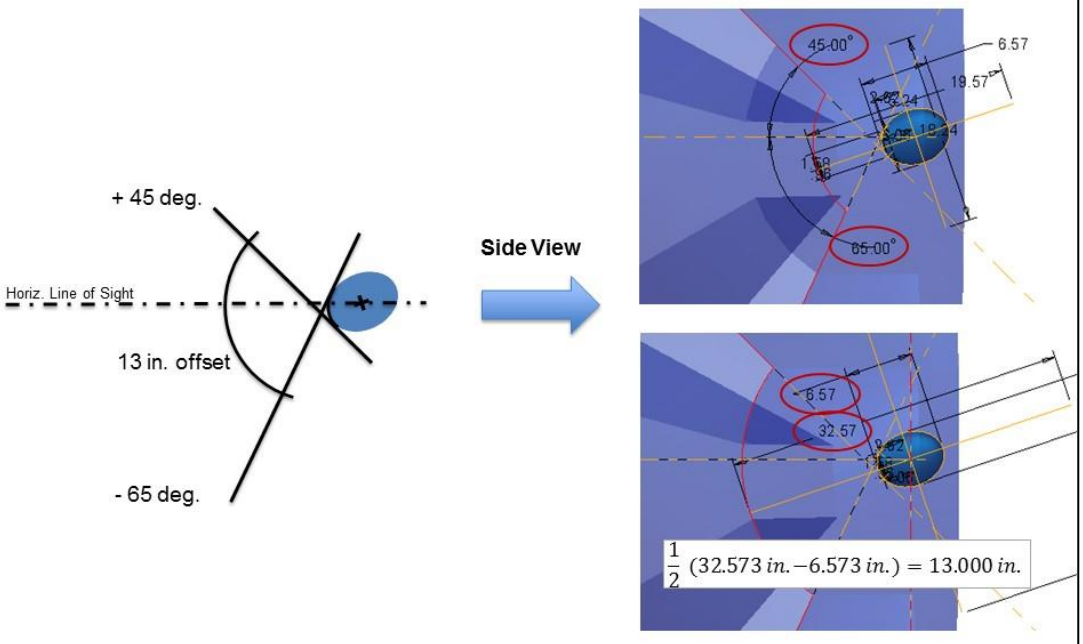
The effective viewing distance shall not be less than 13 inches.



Intent | CAD Implementation

40

Test #1: Tertiary Vision Zone (cont.)



Intent | CAD Implementation

41

Test #1 Bonus Feature: Ground Intercept

When the location of the occupant workspace is known with respect to the rest of the vehicle and the ground, the model is able to show the lowest line of sight in front of the driver to a desired ground intercept. It is depicted by a line tangent to the bottom of the eyellipse and through a user entered value for ground intercept.

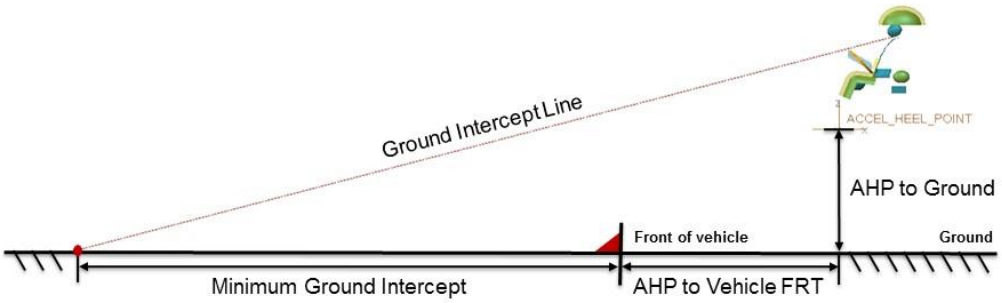
Usage

The ground intercept will remain visible by the target percentage of the population (e.g., 90%) as long as vehicle geometry remains below the Ground Intercept Line.

TARDEC CAD Model Inputs

- Consider Ground Intercept (Yes No)
- Minimum Ground Intercept
- Distance AHP to Vehicle FRT
- Distance AHP to Ground

TARDEC CAD Model Geometry



42

Test #1: Baseline Comparison

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	8.9	30.9	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

The 2015 Boundary Manikins are nominally positioned as follows:

- Hip and eye point locations, calculated using the same data underlying the creation of the accommodation boundaries, control manikin position
- Torso angles are calculated to allow manikins to simultaneously hold hip and eye points, using the following assumptions:
  - the torso is in a functional posture for driving
  - the head is held level
  - angle differences between the head and torso are evenly split between the top and bottom of the neck
- Leg angles are calculated such that the heels are on the AHP (in side view) and knees are splayed to the mean knee locations (by gender)
- Arm angles are calculated such that lower arms are parallel to ground, upper arms are perpendicular to lower arms, and elbows are splayed to the mean elbow locations (by gender)

43

Test #1: Boundary Manikin Positioning

Boundary manikins are positioned using hip and eye points calculated using equations from UMTRI's Excel spreadsheet "Seated Soldier Posture Prediction 2014-09-01".

Inputs

Vehicle Environment
- Steering Wheel Height (H17) } SWP
- Steering Wheel Fore-Aft (L11) }

Boundary Manikin Anthropometry
- Stature*
- Body Weight
- Erect Seating Height

Outputs

Hip Locator Coordinates

Eye Locator Coordinates

Anthropometric values, used for all test cases, are as follows:

DHM #1 Small Overall Female		DHM #4 Widest Shoulders Male		DHM #7 large Overall Male	
Stature	1507 mm	Stature	1887 mm	Stature	1962 mm
Body Weight	50.2 kg	Body Weight	86.1 kg	Body Weight	108 kg
Erect Sitting Height	779 mm	Erect Sitting Height	965 mm	Erect Sitting Height	998 mm
DHM #2 Small Overall Male		**DHM #5 longest Torso Male**			
Stature	1643 mm	Stature	1890 mm		
Body Weight	66 kg	Body Weight	85.9 kg		
Erect Sitting Height	842 mm	Erect Sitting Height	1004 mm		
DHM #3 Average Size Male		**DHM #6 Longest Legs Male**			
Stature	1804 mm	Stature	1918 mm		
Body Weight	79.5 kg	Body Weight	94.4 kg		
Erect Sitting Height	920 mm	Erect Sitting Height	932 mm		

*Note: Values for stature include 1.5 inches representing boot heel thickness.

44

Test #1: Numerical Results, Manikin Positioning

Small Overall Female					
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	20.647	in	20.647	in	0.000	in
POSTURE_DHM1_HIP_Z	18.060	in	18.060	in	0.000	in
POSTURE_DHM1_EYE_X	21.622	in	21.622	in	0.000	in
POSTURE_DHM1_EYE_Z	40.128	in	40.128	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	22.769	in	22.769	in	0.000	in
POSTURE_DHM2_HIP_Z	18.169	in	18.169	in	0.000	in
POSTURE_DHM2_EYE_X	22.873	in	22.873	in	0.000	in
POSTURE_DHM2_EYE_Z	41.895	in	41.895	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	24.965	in	24.965	in	0.000	in
POSTURE_DHM3_HIP_Z	18.169	in	18.169	in	0.000	in
POSTURE_DHM3_EYE_X	24.282	in	24.282	in	0.000	in
POSTURE_DHM3_EYE_Z	44.119	in	44.119	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	25.973	in	25.973	in	0.000	in
POSTURE_DHM4_HIP_Z	18.157	in	18.157	in	0.000	in
POSTURE_DHM4_EYE_X	24.938	in	24.938	in	0.000	in
POSTURE_DHM4_EYE_Z	45.397	in	45.397	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	25.216	in	25.216	in	0.000	in
POSTURE_DHM5_HIP_Z	18.151	in	18.151	in	0.000	in
POSTURE_DHM5_EYE_X	24.448	in	24.448	in	0.000	in
POSTURE_DHM5_EYE_Z	46.398	in	46.398	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	27.489	in	27.489	in	0.000	in
POSTURE_DHM6_HIP_Z	18.222	in	18.222	in	0.000	in
POSTURE_DHM6_EYE_X	25.858	in	25.858	in	0.000	in
POSTURE_DHM6_EYE_Z	44.618	in	44.618	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	27.314	in	27.314	in	0.000	in
POSTURE_DHM7_HIP_Z	18.320	in	18.320	in	0.000	in
POSTURE_DHM7_EYE_X	25.635	in	25.635	in	0.000	in
POSTURE_DHM7_EYE_Z	46.357	in	46.357	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

45

Test #1: Small Overall Female

UMTRI Spreadsheet Calculations*

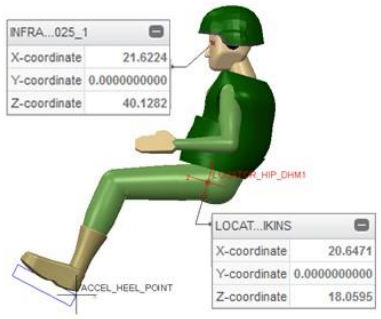
	ACU	PPE	ENC			
Hip re AHP X	524.4	524.4	542.0	→	20.647	in
Hip re AHP Z	458.7	458.7	458.7	→	18.060	in
Eye re AHP X	585.2	549.2	546.2	→	21.622	in
Eye re AHP Z	1019.3	1019.3	1019.3	→	40.128	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	20.647	in
POSTURE_DHM1_HIP_Z	18.060	in
POSTURE_DHM1_EYE_X	21.622	in
POSTURE_DHM1_EYE_Z	40.128	in

TARDEC CAD Model Geometry



Side View

Front View

46

Test #1: Small Overall Male

UMTRI Spreadsheet Calculations*

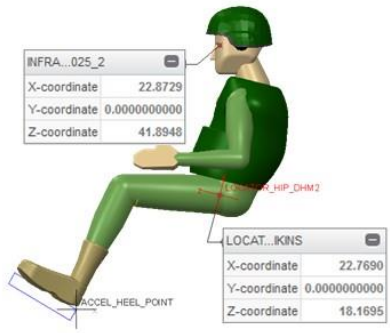
	ACU	PPE	ENC			
Hip re AHP X	578.3	578.3	595.9	→	22.769	in
Hip re AHP Z	461.5	461.5	461.5	→	18.169	in
Eye re AHP X	617.0	581.0	578.0	→	22.873	in
Eye re AHP Z	1064.1	1064.1	1064.1	→	41.895	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	22.769	in
POSTURE_DHM2_HIP_Z	18.169	in
POSTURE_DHM2_EYE_X	22.873	in
POSTURE_DHM2_EYE_Z	41.895	in

TARDEC CAD Model Geometry



Side View

Front View

47

Test #1: Average Size Male

UMTRI Spreadsheet Calculations*

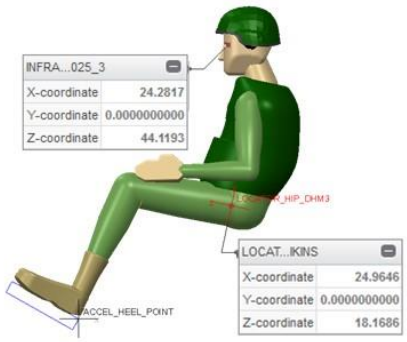
	ACU	PPE	ENC			
Hip re AHP X	634.1	634.1	651.7	→	24.965	in
Hip re AHP Z	461.5	461.5	461.5	→	18.169	in
Eye re AHP X	652.8	616.8	613.8	→	24.282	in
Eye re AHP Z	1120.6	1120.6	1120.6	→	44.119	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	24.965	in
POSTURE_DHM3_HIP_Z	18.169	in
POSTURE_DHM3_EYE_X	24.282	in
POSTURE_DHM3_EYE_Z	44.119	in

TARDEC CAD Model Geometry



Side View

Front View

48

Test #1: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

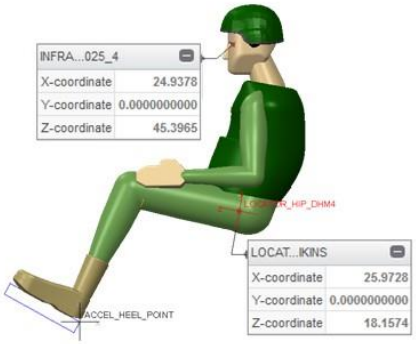
	ACU	PPE	ENC			
Hip re AHP X	659.7	659.7	677.3	→	25.973	in
Hip re AHP Z	461.2	461.2	461.2	→	18.157	in
Eye re AHP X	669.4	633.4	630.4	→	24.938	in
Eye re AHP Z	1153.1	1153.1	1153.1	→	45.397	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	25.973	in
POSTURE_DHM4_HIP_Z	18.157	in
POSTURE_DHM4_EYE_X	24.938	in
POSTURE_DHM4_EYE_Z	45.397	in

TARDEC CAD Model Geometry



Side View

Front View

49

Test #1: Longest Torso Male

UMTRI Spreadsheet Calculations*

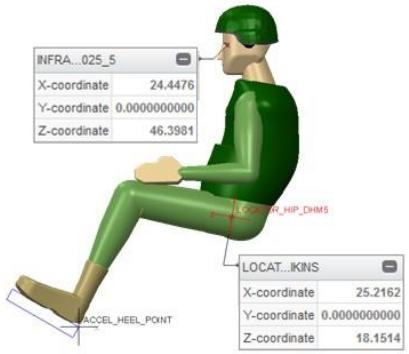
	ACU	PPE	ENC			
Hip re AHP X	640.5	640.5	658.1	→	25.216	in
Hip re AHP Z	461.0	461.0	461.0	→	18.151	in
Eye re AHP X	657.0	621.0	618.0	→	24.448	in
Eye re AHP Z	1178.5	1178.5	1178.5	→	46.398	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	25.216	in
POSTURE_DHM5_HIP_Z	18.151	in
POSTURE_DHM5_EYE_X	24.448	in
POSTURE_DHM5_EYE_Z	46.398	in

TARDEC CAD Model Geometry



Side View

Front View

50

Test #1: Longest Legs Male

UMTRI Spreadsheet Calculations*

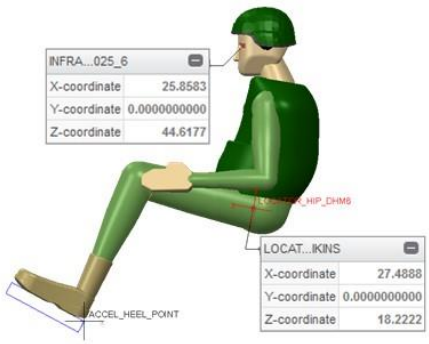
	ACU	PPE	ENC			
Hip re AHP X	698.2	698.2	715.8	→	27.489	in
Hip re AHP Z	462.8	462.8	462.8	→	18.222	in
Eye re AHP X	692.8	656.8	653.8	→	25.858	in
Eye re AHP Z	1133.3	1133.3	1133.3	→	44.618	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	27.489	in
POSTURE_DHM6_HIP_Z	18.222	in
POSTURE_DHM6_EYE_X	25.858	in
POSTURE_DHM6_EYE_Z	44.618	in

TARDEC CAD Model Geometry



Side View

Front View

51

Test #1: Large Overall Male

UMTRI Spreadsheet Calculations*

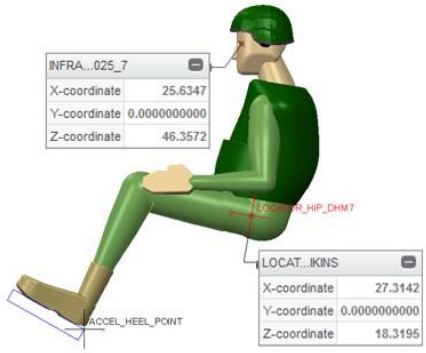
	ACU	PPE	ENC			
Hip re AHP X	693.8	693.8	711.4	→	27.314	in
Hip re AHP Z	465.3	465.3	465.3	→	18.320	in
Eye re AHP X	687.1	651.1	648.1	→	25.635	in
Eye re AHP Z	1177.5	1177.5	1177.5	→	46.357	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	27.314	in
POSTURE_DHM7_HIP_Z	18.320	in
POSTURE_DHM7_EYE_X	25.635	in
POSTURE_DHM7_EYE_Z	46.357	in

TARDEC CAD Model Geometry



Side View

Front View

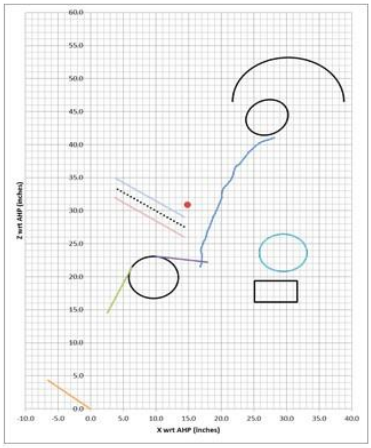
52

10.7.2 TEST #2 – VARY STEERING WHEEL POINT IN FORE-AFT (X) DIRECTION

Test #2: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**14.8**	30.9	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

53

Test #2: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	14.800	in	14.800	in	0.000	in
STEERING_WHEEL_Z	30.900	in	30.900	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	33.223	deg	33.223	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-6.587	in	-6.587	in	0.000	in
BOFRP (Z)	4.314	in	4.314	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	28.363	in	28.364	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	17.767	in	17.767	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.872	deg	16.868	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.070	deg	27.074	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	26.998	in	26.998	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	44.124	in	44.124	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	30.242	in	30.242	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	46.542	in	46.542	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
KNEE_CONTOUR_WEIGHTED_CENT_X	9.627	in	9.627	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.085	in	7.085	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.897	in	19.897	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.587	in	7.589	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.350	in	6.350	in	0.000	in
KNEE_SHIN_ANGLE	28.445	deg	28.445	deg	0.000	deg
KNEE_THIGH_ANGLE	6.124	deg	6.124	deg	0.000	deg
Torso Boundary						
TORSO_WEIGHTED_REF_PT_PPE_X	22.231	in	22.231	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.070	in	35.070	in	0.000	in
Elbow Boundary						
ELBOW_WEIGHTED_CENT_X	29.463	in	29.463	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	23.610	in	23.610	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

54

Test #2: Surrogate Steering Wheel

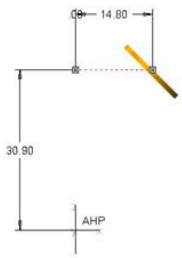
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	14.800	30.900

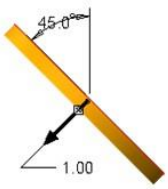
TARDEC CAD Model Calculations

STEERING_WHEEL_X	14.800	in
STEERING_WHEEL_Z	30.900	in

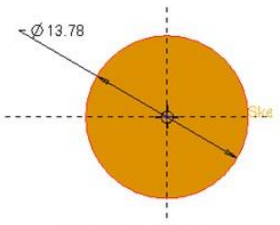
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

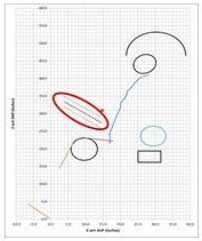
Side View **Steering Wheel Geometry**

55

Test #2: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

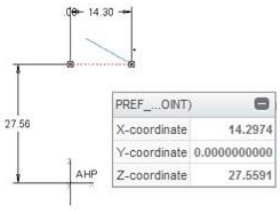
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



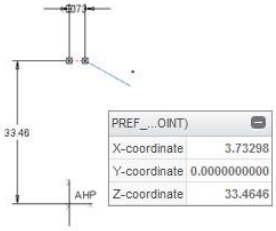
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



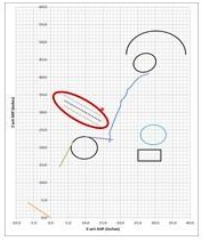
Preference Line Endpoint, Max

56

Test #2: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

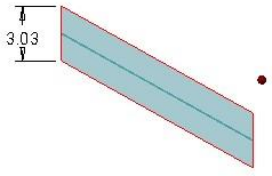
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



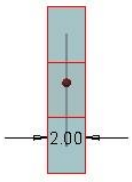
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

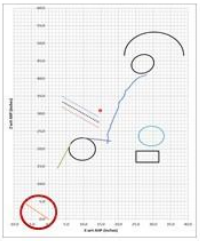
*Given value, not calculated

57

Test #2: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

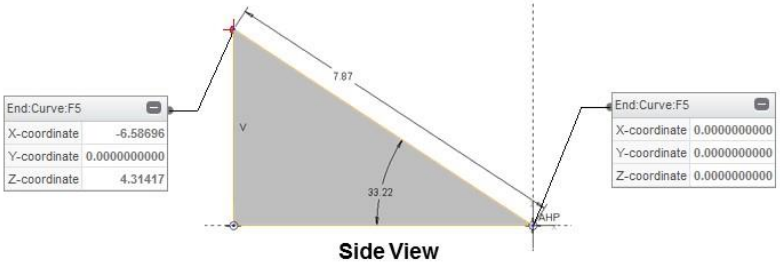
Accelerator Plane Angle (APA)	33.223 deg	
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-6.587	4.314



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	33.223	deg

TARDEC CAD Model Geometry



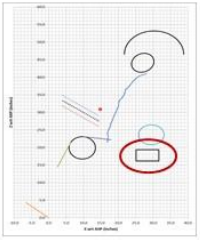
Side View

58

Test #2: Seat Track Travel Range

UMTRI Spreadsheet Calculations

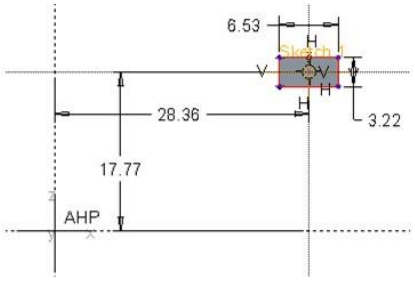
Center of Travel (X)	28.363	in
Center of Travel (Z)	17.767	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.223	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	28.364	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	17.767	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 14.8 in.
Steering Wheel Point, Z (wrt AHP): 30.9 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 28.4 in., Z = 17.8 in.)

59

Test #2: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	16.872 deg
Rear of Range	27.070 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.868	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.074	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 28.4 in., Z = 17.8 in.)

Seat Back Angle (wrt vertical): 16.9^{o} to 27.1^{o}

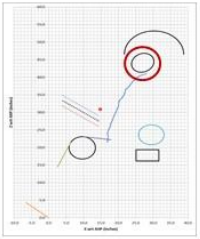
Warnings
-- Manikins with upper legs less than 5 deg above horiz:
#1 #2

60

Test #2: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	26.998	1.280*	44.124
Left	26.998	-1.280*	44.124



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		26.998	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		44.124	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

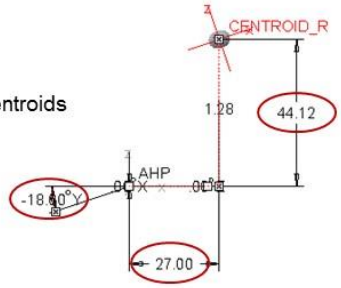
*Given value, not calculated

61

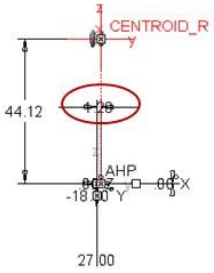
Test #2: Eyellipse (cont.)

TARDEC CAD Model Geometry

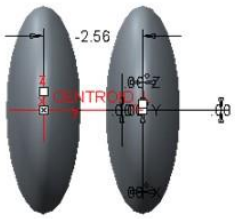
Centroids



Side View

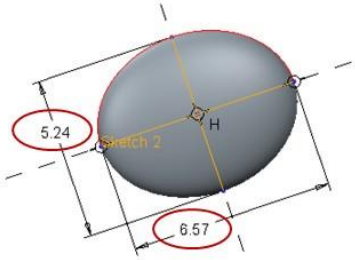


Rear View

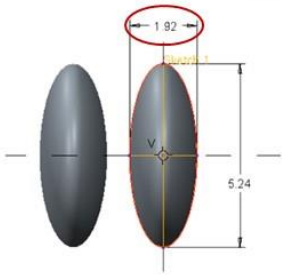


Rear View

Axis Lengths



Side View

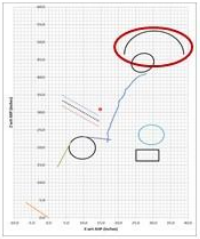


Rear View (Rotated)

Test #2: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	30.242	2.185*	46.542
Left	30.242	-2.185*	46.542



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.045	in
Axis Length (Z)	→	13.292	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.292	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		30.242	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		46.542	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.048	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.296	in

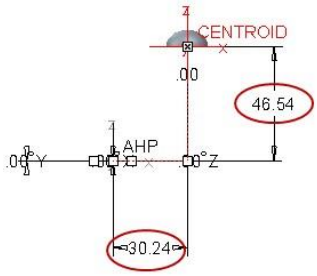
$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

*Given value, not calculated

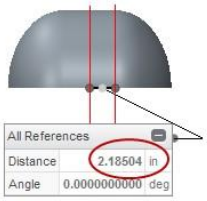
Test #2: Helmet Boundary (cont.)

TARDEC CAD Model Result

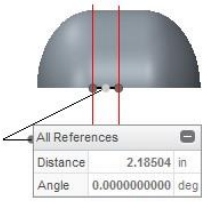
Centroids



Side View

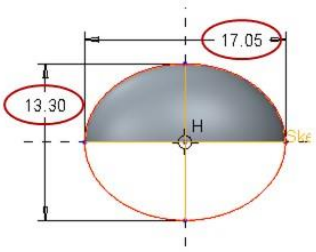


Rear View

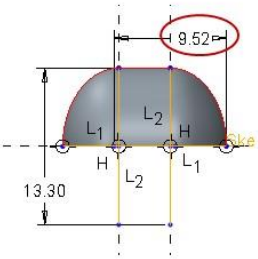


Rear View

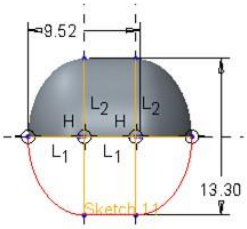
Axis Lengths



Side View



Rear View



Rear View

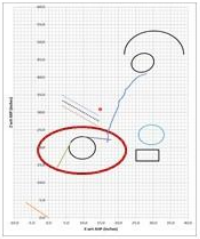
64

Test #2: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	9.627	7.085	19.897
Left	9.627	-7.085	19.897

Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.587	in
Axis Length (Z)	→	6.350	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.671	in
Axis Length (Z)	→	6.350	in
Leg Segment Angle wrt Vertical		28.445	deg
Thigh Segment Angle wrt Horizontal		6.124	deg



TARDEC CAD Model Calculations

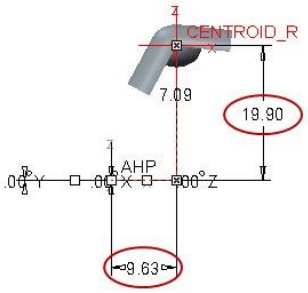
KNEE_CONTOUR_WEIGHTED_CENT_X		9.627	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		7.085	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		19.897	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.589	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	6.350	in
KNEE_SHIN_ANGLE		28.445	deg
KNEE_THIGH_ANGLE		6.124	deg

65

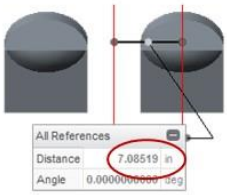
Test #2: Knee Boundary (cont.)

TARDEC CAD Model Result

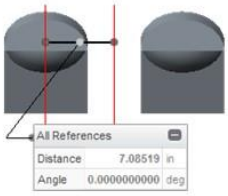
Centroids



Side View

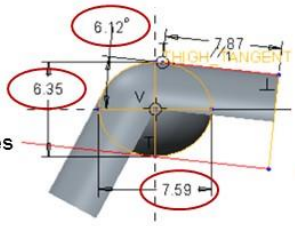


Rear View

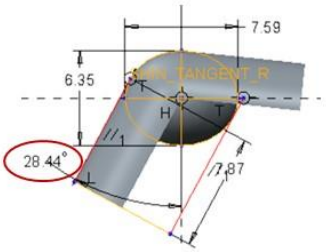


Rear View

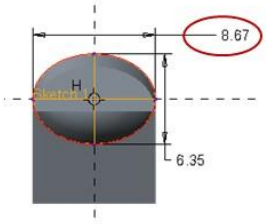
Axis Lengths
Shin/Thigh Angles



Side View



Side View



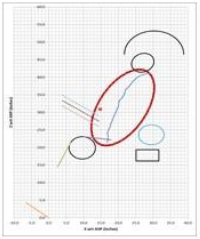
Rear View

66

Test #2: Torso Boundary (PPE)

UMTRI Spreadsheet Calculations

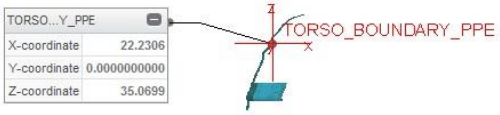
Mean Reference Point	X (in)	Z (in)
PPE	22.231	35.070
ENC	15.266	29.538



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	22.231	in
TORSO_WEIGHTED_REF_PT_PPE_Z	35.070	in

TARDEC CAD Model Geometry



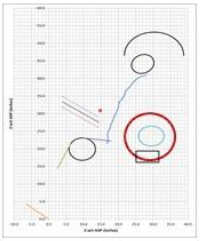
Side View

67

Test #2: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	29.463	12.353	23.610
Left	29.463	-12.353	23.610



Side View of Elbow Contours (X, Z)
Axis Length (X) → 7.303 in
Axis Length (Z) → 5.665 in

Rear View of Elbow Contours (Y, Z)
Axis Length (Y) → 3.424 in
Axis Length (Z) → 5.665 in

TARDEC CAD Model Calculations

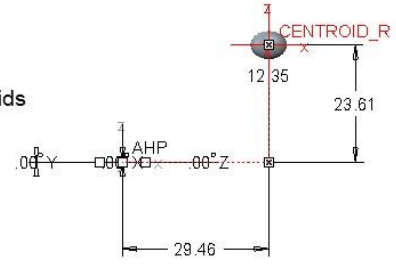
ELBOW_WEIGHTED_CENT_X	29.463	in
ELBOW_WEIGHTED_CENT_Y	12.353	in
ELBOW_WEIGHTED_CENT_Z	23.610	in
ELBOW_X_AXIS_LENGTH →	7.305	in
ELBOW_Y_AXIS_LENGTH →	3.425	in
ELBOW_Z_AXIS_LENGTH →	5.668	in

68

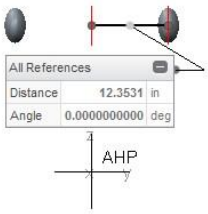
Test #2: Elbow Boundary (cont.)

TARDEC CAD Model Result

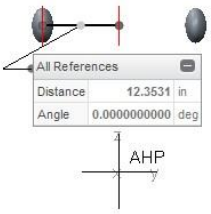
Centroids



Side View

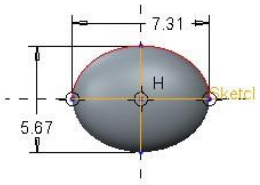


Rear View

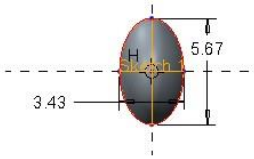


Rear View

Axis Lengths



Side View



Rear View

69

Test #2: Vary Steering Wheel Point (SWP)

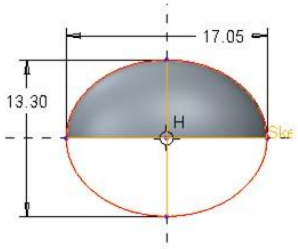
Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**14.8**	30.9	No	SAE J826

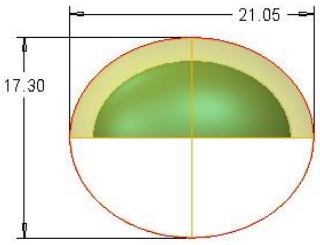
Clearance (2.0 inches), Shown in Yellow

TARDEC CAD Model

70

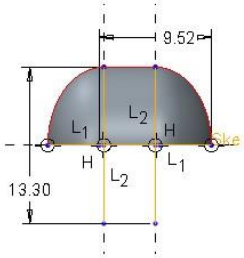
Test #2: Clearance, Helmet Boundary

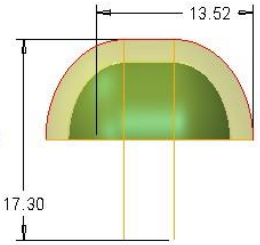


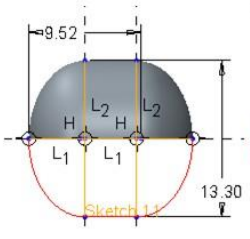


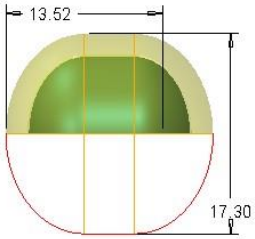
$$Sample\ Calculation: \frac{1}{2}\,(21.048\,in. - 17.048\,in.) = 2.000\,in.\,clearance$$

Side View





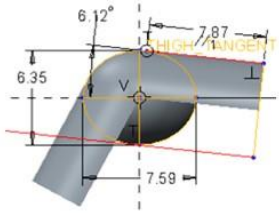


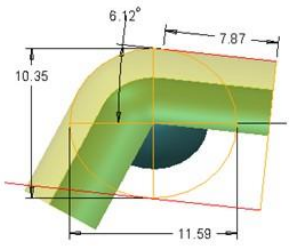


Rear View

71

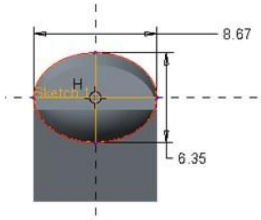
Test #2: Clearance, Knee Boundary

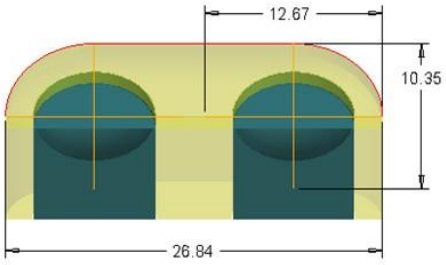




$$Sample\ Calculation: \frac{1}{2}\,(10.350\ in. - 6.350\ in.) = 2.000\ in. clearance$$

Side View

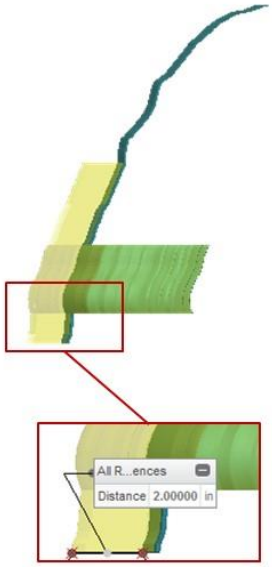


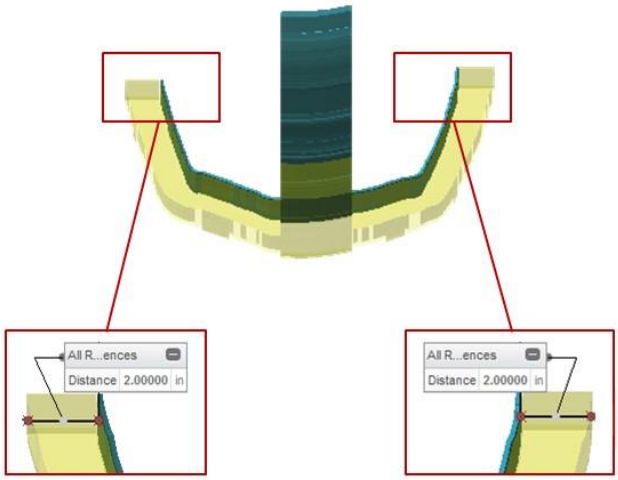


Rear View

72

Test #2: Clearance, Torso Boundary (PPE)





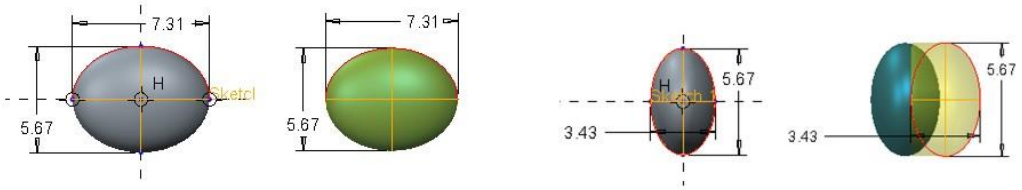
Side View **Top View**

73

Test #2: Clearance, Elbow Boundary

Sample Calculation: $14.353\ in. - 12.353\ in. = \ 2.000\ in.\ clearance$

Rear View



Side View **Rear View**

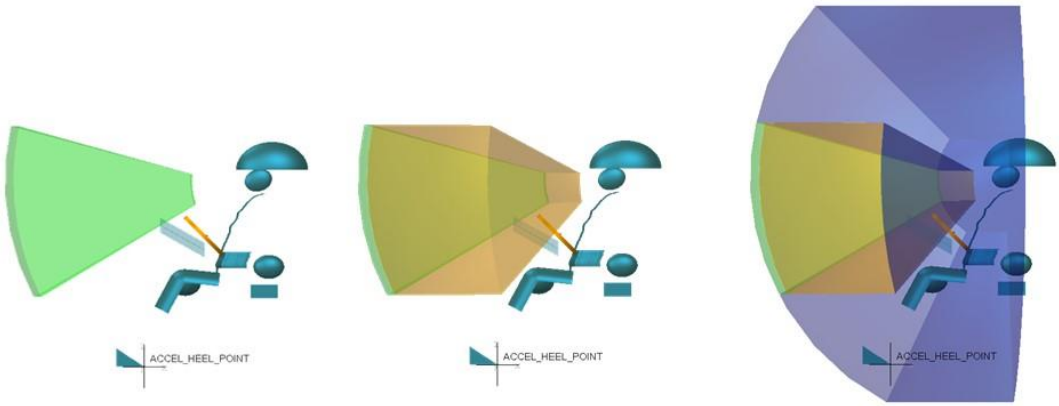
74

Test #2: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**14.8**	30.9	No	SAE J826

Vision Zones

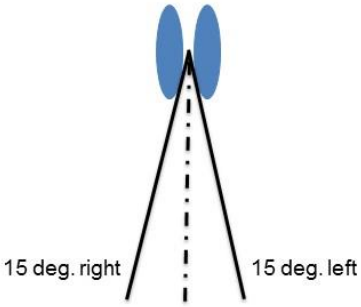
Vison zones are constructed geometrically; no calculations are involved.



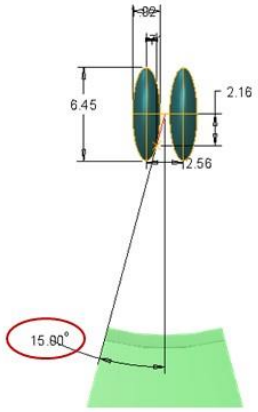
Primary Zone Secondary Zone Tertiary Zone

75

Test #2: Primary Vision Zone



Top View

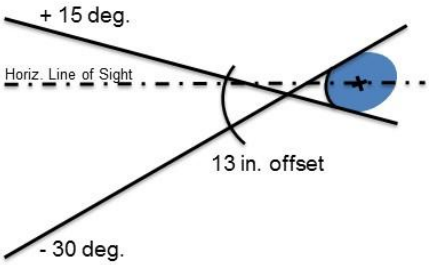


Intent

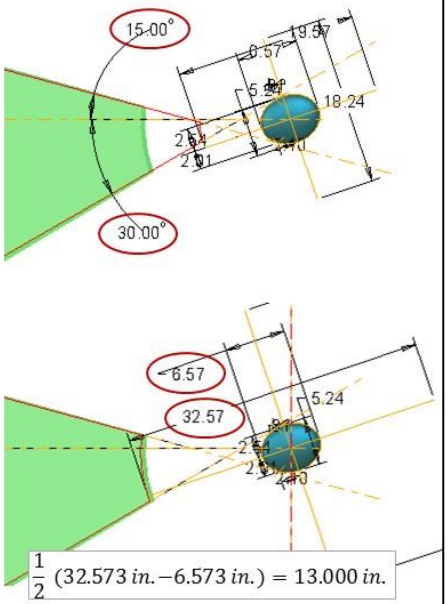
CAD Implementation

76

Test #2: Primary Vision Zone (cont.)



Side View

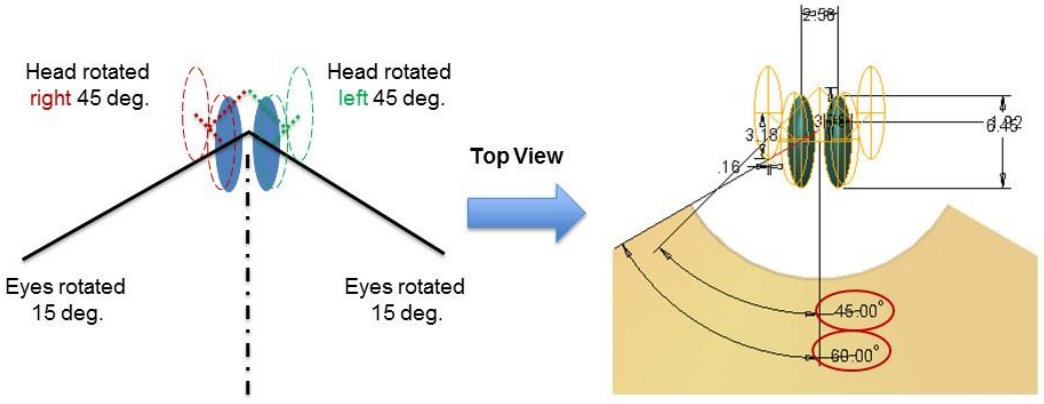


Intent

CAD Implementation

77

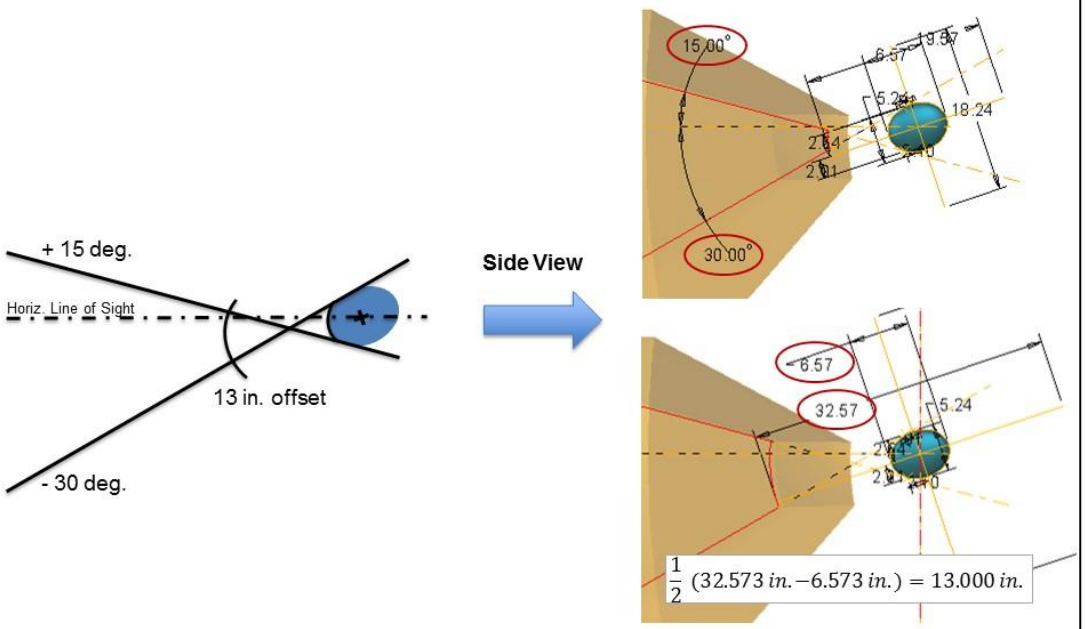
Test #2: Secondary Vision Zone



Intent | CAD Implementation

78

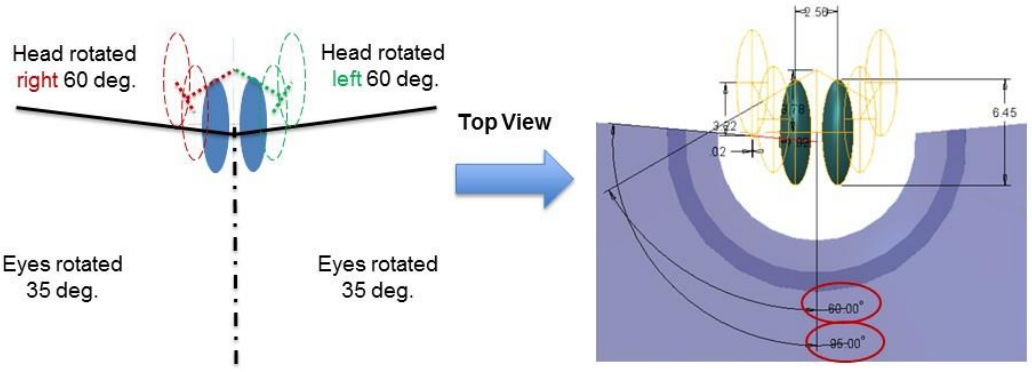
Test #2: Secondary Vision Zone (cont.)



Intent | CAD Implementation

79

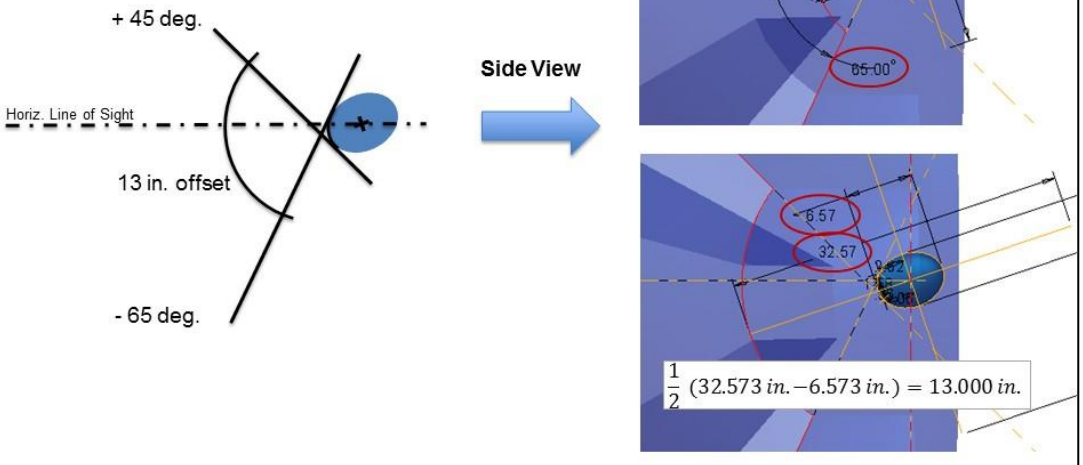
Test #2: Tertiary Vision Zone



Intent **CAD Implementation**

80

Test #2: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

81

Test #2: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**14.8**	30.9	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

82

Test #2: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.709	in	23.709	in	0.000	in
POSTURE_DHM1_HIP_Z	17.617	in	17.617	in	0.000	in
POSTURE_DHM1_EYE_X	25.180	in	25.180	in	0.000	in
POSTURE_DHM1_EYE_Z	40.128	in	40.128	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.831	in	25.831	in	0.000	in
POSTURE_DHM2_HIP_Z	17.727	in	17.727	in	0.000	in
POSTURE_DHM2_EYE_X	26.431	in	26.431	in	0.000	in
POSTURE_DHM2_EYE_Z	41.895	in	41.895	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	28.027	in	28.027	in	0.000	in
POSTURE_DHM3_HIP_Z	17.726	in	17.726	in	0.000	in
POSTURE_DHM3_EYE_X	27.839	in	27.839	in	0.000	in
POSTURE_DHM3_EYE_Z	44.119	in	44.119	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	29.035	in	29.035	in	0.000	in
POSTURE_DHM4_HIP_Z	17.715	in	17.715	in	0.000	in
POSTURE_DHM4_EYE_X	28.495	in	28.495	in	0.000	in
POSTURE_DHM4_EYE_Z	45.397	in	45.397	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.278	in	28.278	in	0.000	in
POSTURE_DHM5_HIP_Z	17.709	in	17.709	in	0.000	in
POSTURE_DHM5_EYE_X	28.005	in	28.005	in	0.000	in
POSTURE_DHM5_EYE_Z	46.398	in	46.398	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	30.551	in	30.551	in	0.000	in
POSTURE_DHM6_HIP_Z	17.780	in	17.780	in	0.000	in
POSTURE_DHM6_EYE_X	29.416	in	29.416	in	0.000	in
POSTURE_DHM6_EYE_Z	44.618	in	44.618	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	30.376	in	30.376	in	0.000	in
POSTURE_DHM7_HIP_Z	17.877	in	17.877	in	0.000	in
POSTURE_DHM7_EYE_X	29.192	in	29.192	in	0.000	in
POSTURE_DHM7_EYE_Z	46.357	in	46.357	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

83

Test #2: Small Overall Female

UMTRI Spreadsheet Calculations*

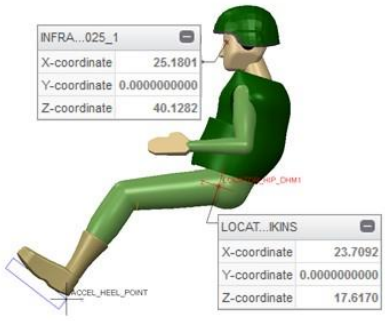
	ACU	PPE	ENC			
Hip re AHP X	602.2	602.2	619.8	→	23.709	in
Hip re AHP Z	447.5	447.5	447.5	→	17.617	in
Eye re AHP X	675.6	639.6	636.6	→	25.180	in
Eye re AHP Z	1019.3	1019.3	1019.3	→	40.128	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.709	in
POSTURE_DHM1_HIP_Z	17.617	in
POSTURE_DHM1_EYE_X	25.180	in
POSTURE_DHM1_EYE_Z	40.128	in

TARDEC CAD Model Geometry



Side View

Front View

84

Test #2: Small Overall Male

UMTRI Spreadsheet Calculations*

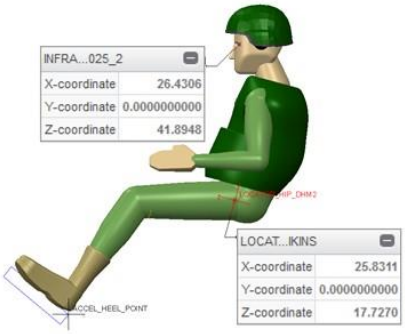
	ACU	PPE	ENC			
Hip re AHP X	656.1	656.1	673.7	→	25.831	in
Hip re AHP Z	450.3	450.3	450.3	→	17.727	in
Eye re AHP X	707.3	671.3	668.3	→	26.431	in
Eye re AHP Z	1064.1	1064.1	1064.1	→	41.895	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.831	in
POSTURE_DHM2_HIP_Z	17.727	in
POSTURE_DHM2_EYE_X	26.431	in
POSTURE_DHM2_EYE_Z	41.895	in

TARDEC CAD Model Geometry



Side View

Front View

85

Test #2: Average Size Male

UMTRI Spreadsheet Calculations*

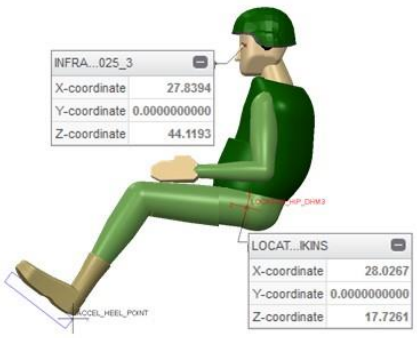
	ACU	PPE	ENC			
Hip re AHP X	711.9	711.9	729.5	→	28.027	in
Hip re AHP Z	450.2	450.2	450.2	→	17.726	in
Eye re AHP X	743.1	707.1	704.1	→	27.839	in
Eye re AHP Z	1120.6	1120.6	1120.6	→	44.119	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	28.027	in
POSTURE_DHM3_HIP_Z	17.726	in
POSTURE_DHM3_EYE_X	27.839	in
POSTURE_DHM3_EYE_Z	44.119	in

TARDEC CAD Model Geometry



Side View

Front View

86

Test #2: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

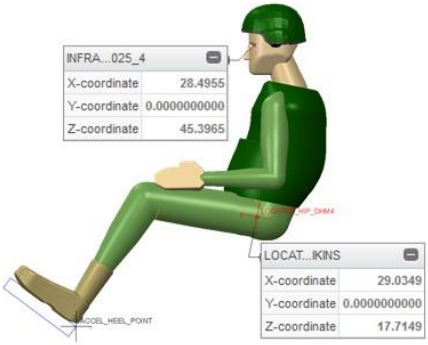
	ACU	PPE	ENC			
Hip re AHP X	737.5	737.5	755.1	→	29.035	in
Hip re AHP Z	450.0	450.0	450.0	→	17.715	in
Eye re AHP X	759.8	723.8	720.8	→	28.495	in
Eye re AHP Z	1153.1	1153.1	1153.1	→	45.397	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	29.035	in
POSTURE_DHM4_HIP_Z	17.715	in
POSTURE_DHM4_EYE_X	28.495	in
POSTURE_DHM4_EYE_Z	45.397	in

TARDEC CAD Model Geometry



Side View

Front View

87

Test #2: Longest Torso Male

UMTRI Spreadsheet Calculations*

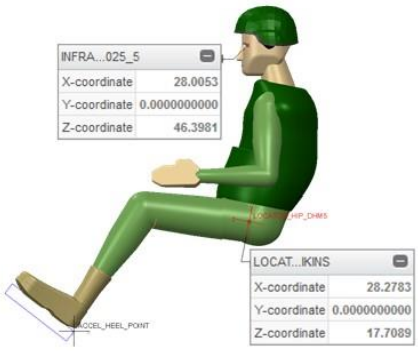
	ACU	PPE	ENC			
Hip re AHP X	718.3	718.3	735.9	→	28.278	in
Hip re AHP Z	449.8	449.8	449.8	→	17.709	in
Eye re AHP X	747.3	711.3	708.3	→	28.005	in
Eye re AHP Z	1178.5	1178.5	1178.5	→	46.398	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.278	in
POSTURE_DHM5_HIP_Z	17.709	in
POSTURE_DHM5_EYE_X	28.005	in
POSTURE_DHM5_EYE_Z	46.398	in

TARDEC CAD Model Geometry



Side View

Front View

88

Test #2: Longest Legs Male

UMTRI Spreadsheet Calculations*

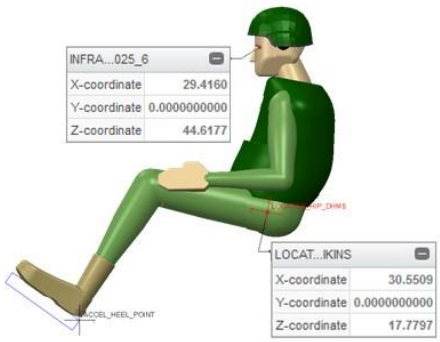
	ACU	PPE	ENC			
Hip re AHP X	776.0	776.0	793.6	→	30.551	in
Hip re AHP Z	451.6	451.6	451.6	→	17.780	in
Eye re AHP X	783.2	747.2	744.2	→	29.416	in
Eye re AHP Z	1133.3	1133.3	1133.3	→	44.618	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.551	in
POSTURE_DHM6_HIP_Z	17.780	in
POSTURE_DHM6_EYE_X	29.416	in
POSTURE_DHM6_EYE_Z	44.618	in

TARDEC CAD Model Geometry



Side View

Front View

89

Test #2: Large Overall Male

UMTRI Spreadsheet Calculations*

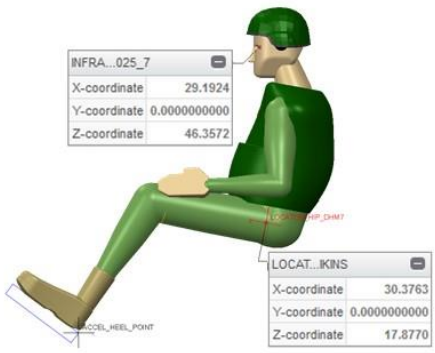
	ACU	PPE	ENC			
Hip re AHP X	771.6	771.6	789.2	→	30.376	in
Hip re AHP Z	454.1	454.1	454.1	→	17.877	in
Eye re AHP X	777.5	741.5	738.5	→	29.192	in
Eye re AHP Z	1177.5	1177.5	1177.5	→	46.357	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.376	in
POSTURE_DHM7_HIP_Z	17.877	in
POSTURE_DHM7_EYE_X	29.192	in
POSTURE_DHM7_EYE_Z	46.357	in

TARDEC CAD Model Geometry



Side View

Front View

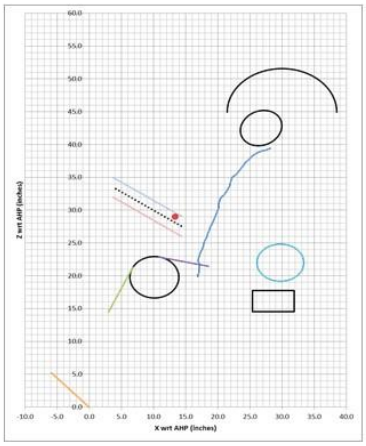
90

10.7.3 TEST #3 – VARY SWP IN FORE-AFT (X) AND VERTICAL (Z) POSITION AND USE ALTERNATE HARP TOOL

Test #3: Vary SWP and Use Alternate HARP Tool

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	13.3	29.0	No	ISO 5353

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

91

Test #3: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	28.617	in	28.619	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.146	in	16.146	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	26.716	in	26.716	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.504	in	42.504	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.960	in	29.960	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.921	in	44.921	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	10.112	in	10.112	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.611	in	7.613	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.317	in	6.317	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	22.289	in	22.288	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.449	in	33.449	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	29.717	in	29.717	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.989	in	21.989	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

92

Test #3: Surrogate Steering Wheel

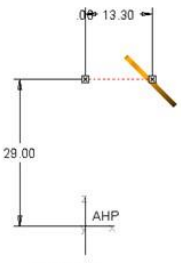
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

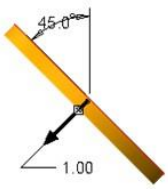
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

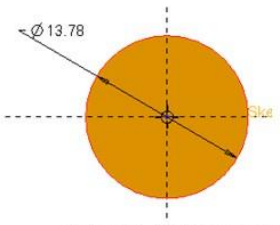
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

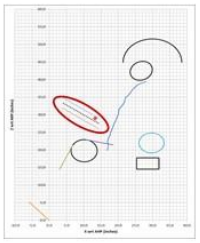
Side View **Steering Wheel Geometry**

93

Test #3: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

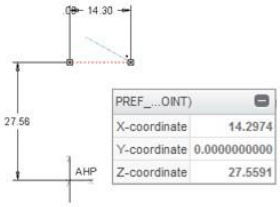
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



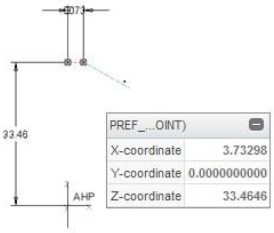
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



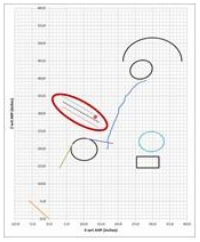
Preference Line Endpoint, Max

94

Test #3: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

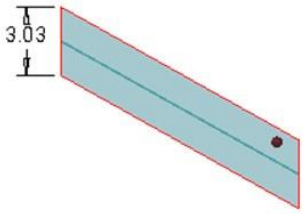
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



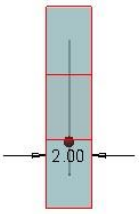
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

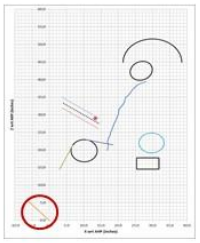
$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

*Given value, not calculated

95

Test #3: Accelerator Plane Angle (APA)



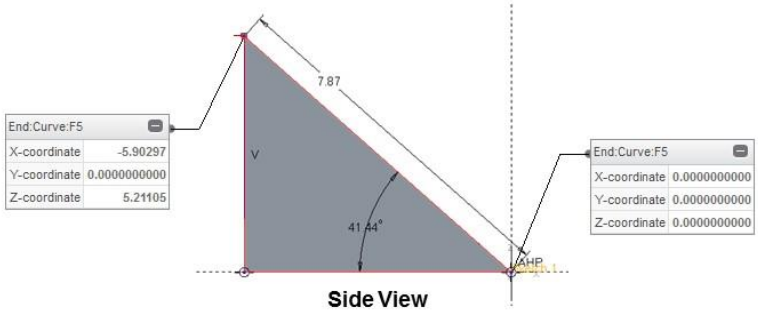
UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA)	41.438 deg	
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211

TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

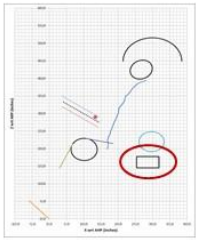
TARDEC CAD Model Geometry



Side View

96

Test #3: Seat Track Travel Range



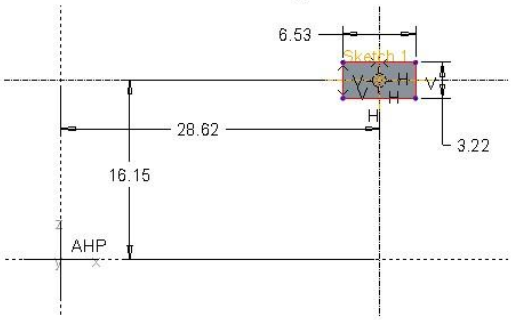
UMTRI Spreadsheet Calculations

Center of Travel (X)	28.617	in
Center of Travel (Z)	16.146	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.223	in

TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	28.619	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.146	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via ISO 5353, @ (X = 28.6 in., Z = 16.1 in.)

97

Test #3: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	16.510 deg
Rear of Range	26.708 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.507	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.712	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via ISO 5353, @ (X = 28.6 in., Z = 16.1 in.)

Seat Back Angle (wrt vertical): 16.5^{o} to 26.7^{o}

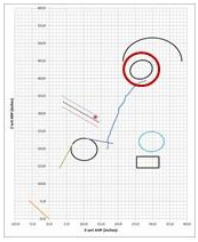
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

98

Test #3: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	26.716	1.280*	42.504
Left	26.716	-1.280*	42.504



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		26.716	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		42.504	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

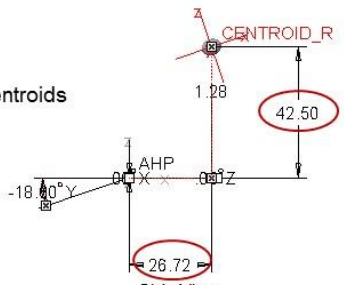
*Given value, not calculated

99

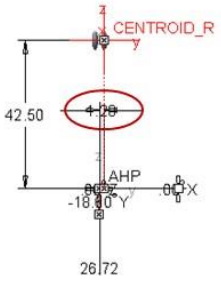
Test #3: Eyellipse (cont.)

TARDEC CAD Model Geometry

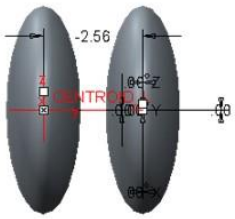
Centroids



Side View

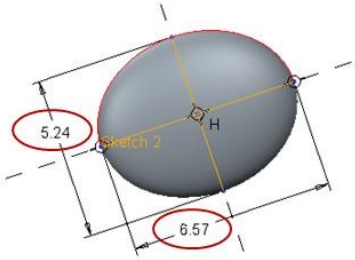


Rear View

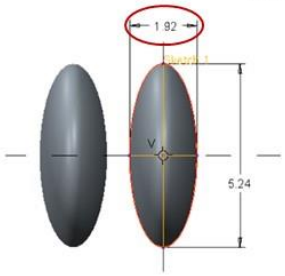


Rear View

Axis Lengths



Side View

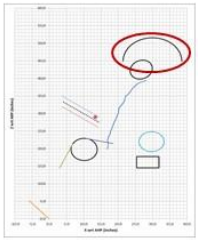


Rear View (Rotated)

Test #3: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	29.960	2.185*	44.921
Left	29.960	-2.185*	44.921



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.045	in
Axis Length (Z)	→	13.292	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.292	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		29.960	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		44.921	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.048	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.296	in

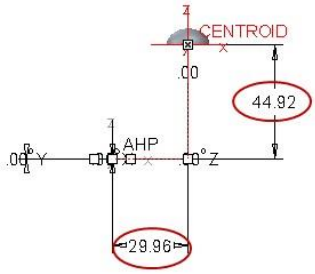
$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

*Given value, not calculated

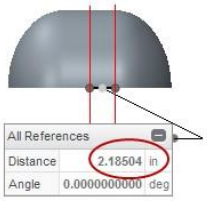
Test #3: Helmet Boundary (cont.)

TARDEC CAD Model Result

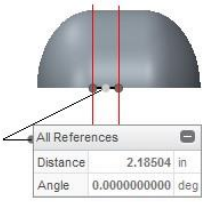
Centroids



Side View

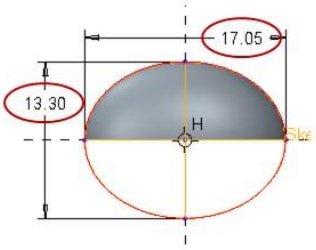


Rear View

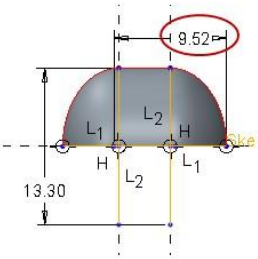


Rear View

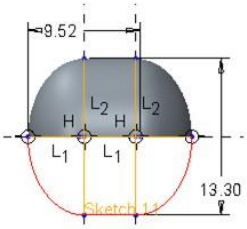
Axis Lengths



Side View



Rear View



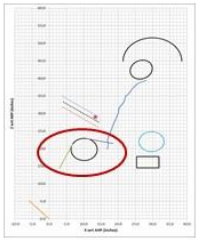
Rear View

102

Test #3: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	10.112	7.331	19.772
Left	10.112	-7.331	19.772



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.611	in
Axis Length (Z)	→	6.317	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.671	in
Axis Length (Z)	→	6.317	in
Leg Segment Angle wrt Vertical		29.013	deg
Thigh Segment Angle wrt Horizontal		10.322	deg

TARDEC CAD Model Calculations

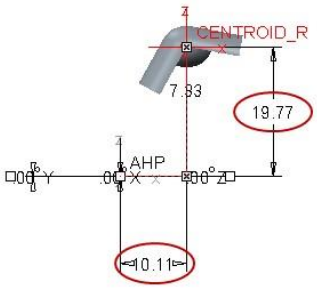
KNEE_CONTOUR_WEIGHTED_CENT_X		10.112	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		7.331	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		19.772	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.613	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	6.317	in
KNEE_SHIN_ANGLE		29.013	deg
KNEE_THIGH_ANGLE		10.322	deg

103

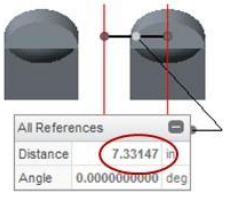
Test #3: Knee Boundary (cont.)

TARDEC CAD Model Result

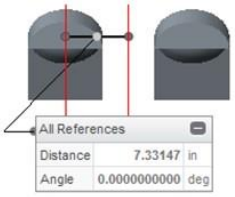
Centroids



Side View

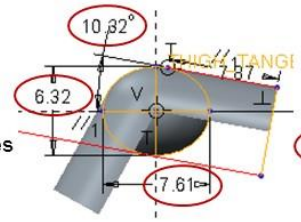


Rear View

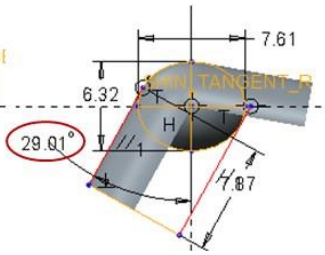


Rear View

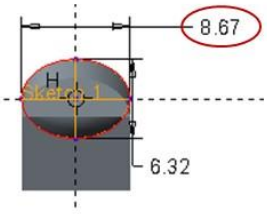
Axis Lengths
Shin/Thigh Angles



Side View



Side View



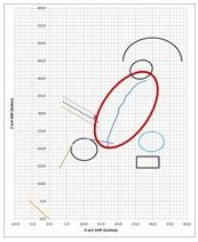
Rear View

104

Test #3: Torso Boundary (PPE)

UMTRI Spreadsheet Calculations

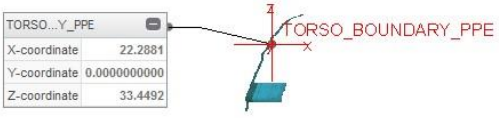
Mean Reference Point	X (in)	Z (in)
PPE	22.289	33.449
ENC	15.520	27.917



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	22.288	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.449	in

TARDEC CAD Model Geometry



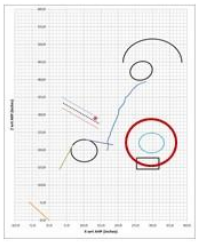
Side View

105

Test #3: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	29.717	12.353	21.989
Left	29.717	-12.353	21.989



Side View of Elbow Contours (X, Z)
Axis Length (X) → 7.303 in
Axis Length (Z) → 5.665 in

Rear View of Elbow Contours (Y, Z)
Axis Length (Y) → 3.424 in
Axis Length (Z) → 5.665 in

TARDEC CAD Model Calculations

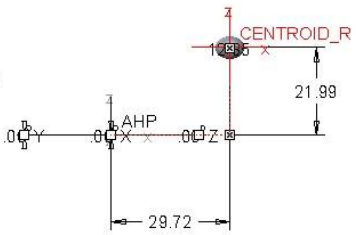
ELBOW_WEIGHTED_CENT_X	29.717	in
ELBOW_WEIGHTED_CENT_Y	12.353	in
ELBOW_WEIGHTED_CENT_Z	21.989	in
ELBOW_X_AXIS_LENGTH →	7.305	in
ELBOW_Y_AXIS_LENGTH →	3.425	in
ELBOW_Z_AXIS_LENGTH →	5.668	in

106

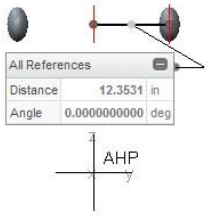
Test #3: Elbow Boundary (cont.)

TARDEC CAD Model Result

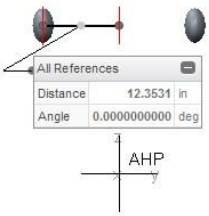
Centroids



Side View

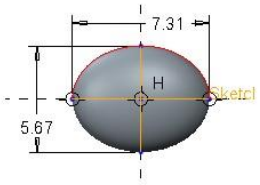


Rear View

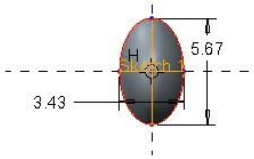


Rear View

Axis Lengths



Side View



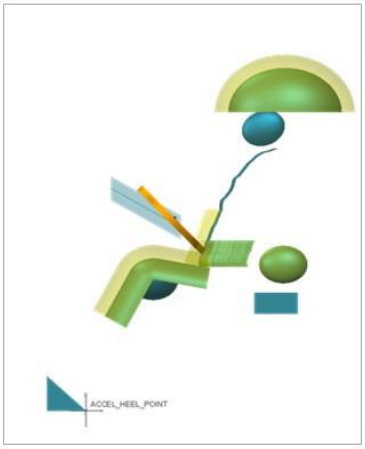
Rear View

107

Test #3: Vary SWP and Use Alternate HARP Tool

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	13.3	29.0	No	ISO 5353

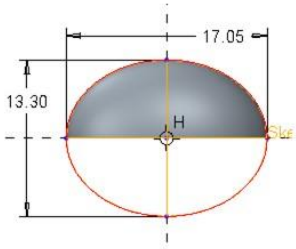
Clearance (2.0 inches), Shown in Yellow

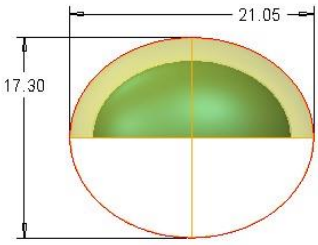


TARDEC CAD Model

108

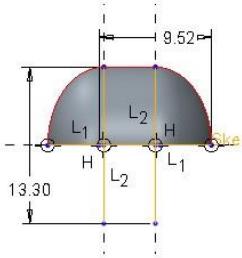
Test #3: Clearance, Helmet Boundary

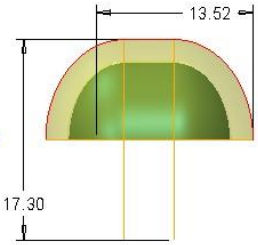


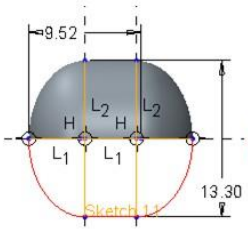


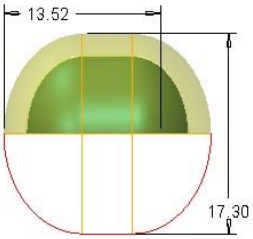
$$Sample\ Calculation: \frac{1}{2}\,(21.048\,in. - 17.048\,in.) = 2.000\,in.\,clearance$$

Side View





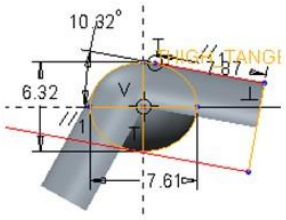


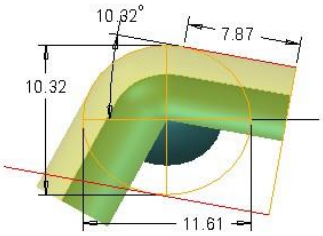


Rear View

109

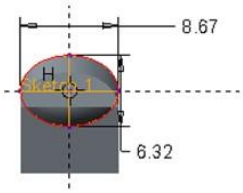
Test #3: Clearance, Knee Boundary

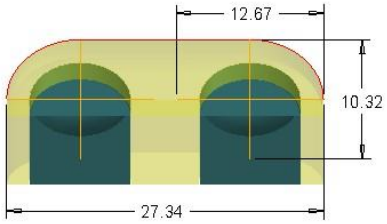




$$Sample\ Calculation: \frac{1}{2}\,(10.317\ in. - 6.317\ in.) = 2.000\ in. clearance$$

Side View

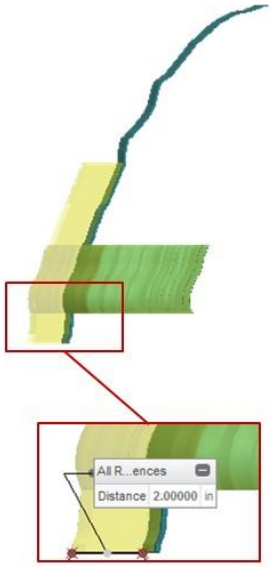


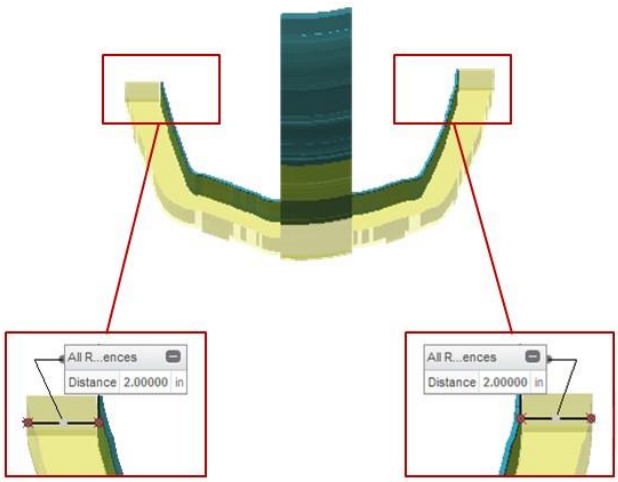


Rear View

110

Test #3: Clearance, Torso Boundary (PPE)





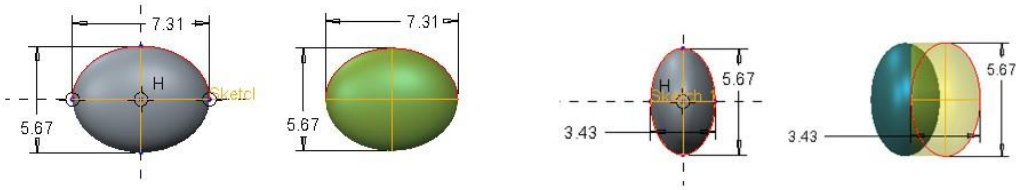
Side View **Top View**

111

Test #3: Clearance, Elbow Boundary

Sample Calculation: $14.353\ in. - 12.353\ in. = \ 2.000\ in.\ clearance$

Rear View



Side View **Rear View**

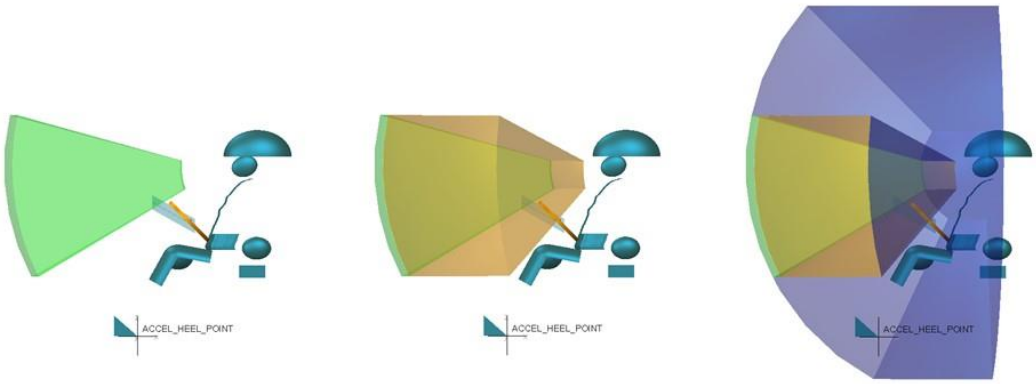
112

Test #3: Vary SWP and Use Alternate HARP Tool

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	13.3	29.0	No	ISO 5353

Vision Zones

Vison zones are constructed geometrically; no calculations are involved.

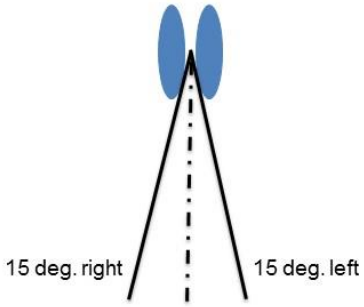


Primary Zone Secondary Zone Tertiary Zone

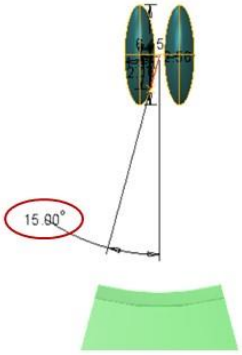
113

Test #3: Primary Vision Zone

Zone Construction



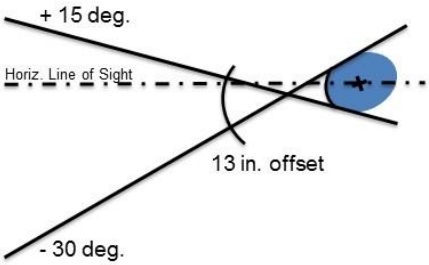
Top View



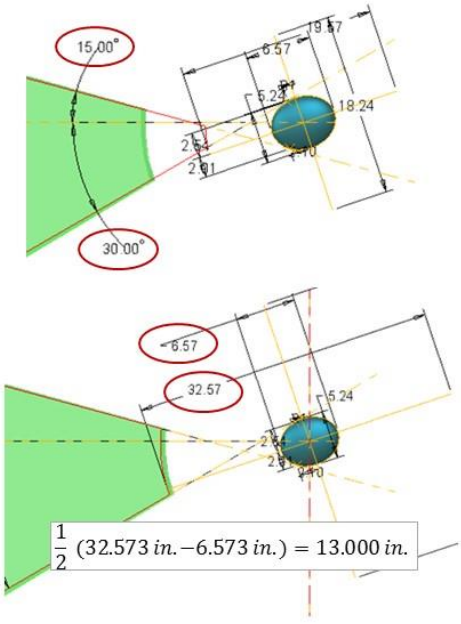
Intent **CAD Implementation**

114

Test #3: Primary Vision Zone (cont.)



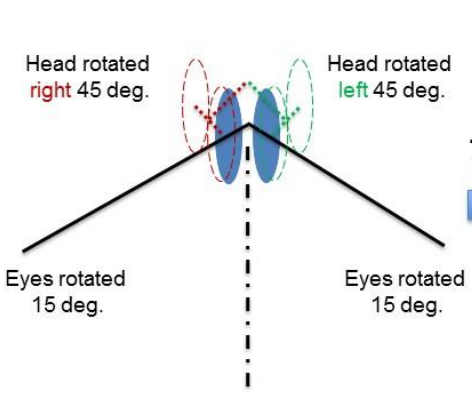
Side View



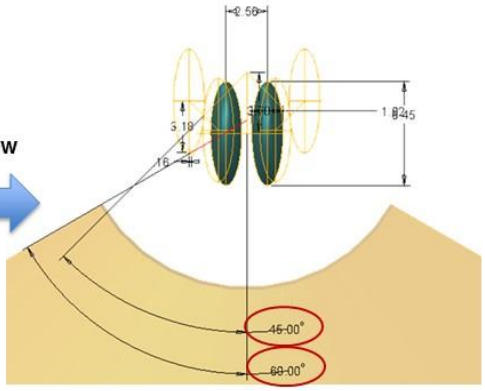
Intent **CAD Implementation**

115

Test #3: Secondary Vision Zone



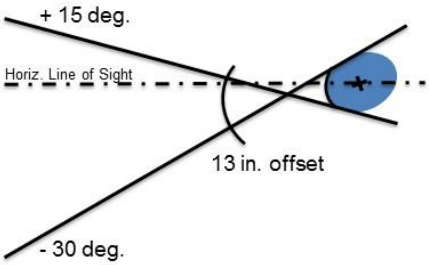
Top View



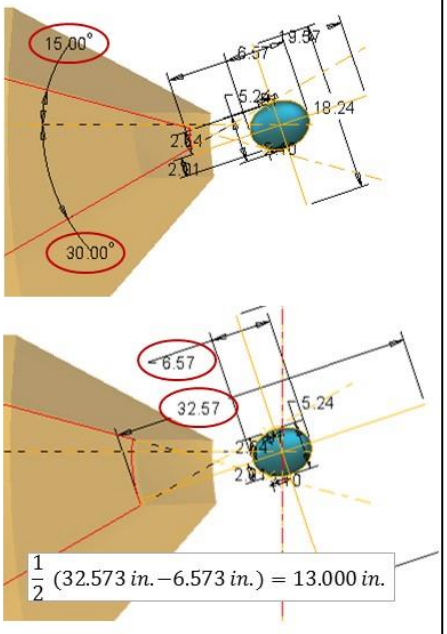
Intent **CAD Implementation**

116

Test #3: Secondary Vision Zone (cont.)



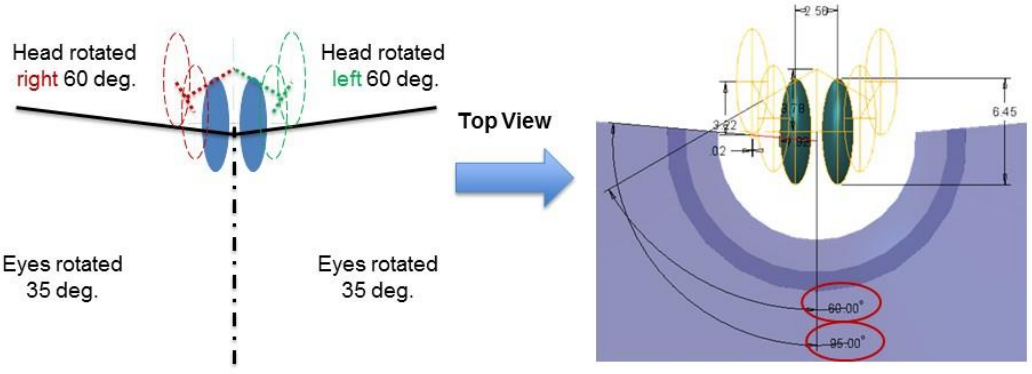
Side View



Intent **CAD Implementation**

117

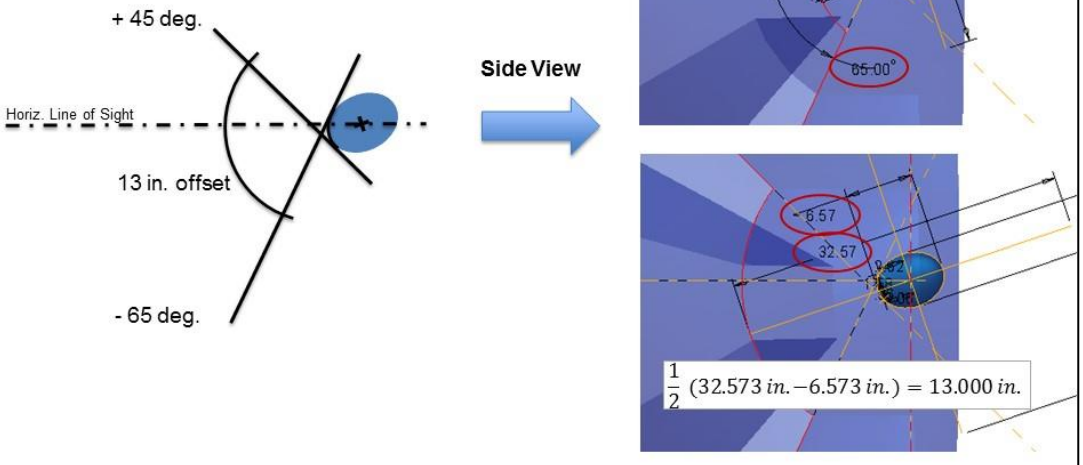
Test #3: Tertiary Vision Zone



Intent **CAD Implementation**

118

Test #3: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

119

Test #3: Vary SWP and Use Alternate HARP Tool

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	13.3	29.0	No	ISO 5353

Boundary Manikin Posture and Position

TARDEC CAD Model

120

Test #3: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

121

Test #3: Small Overall Female

UMTRI Spreadsheet Calculations*

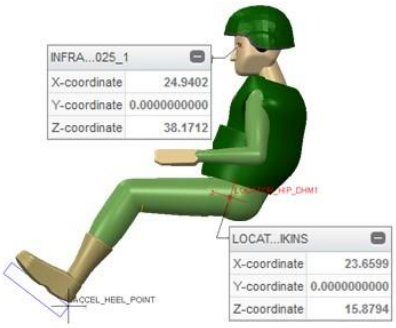
	ACU	PPE	ENC			
Hip re AHP X	601.0	601.0	618.6	→	23.660	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	24.940	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.660	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	24.940	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

122

Test #3: Small Overall Male

UMTRI Spreadsheet Calculations*

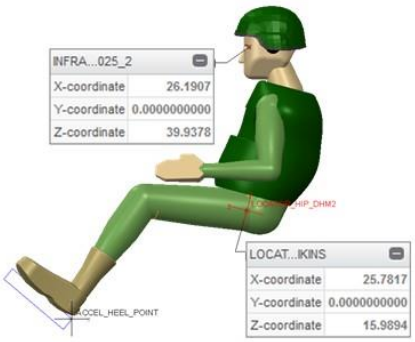
	ACU	PPE	ENC			
Hip re AHP X	654.9	654.9	672.5	→	25.782	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	26.191	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.782	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	26.191	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

123

Test #3: Average Size Male

UMTRI Spreadsheet Calculations*

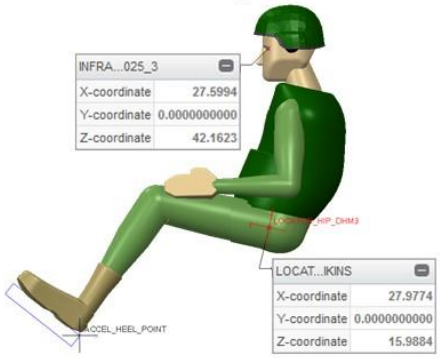
	ACU	PPE	ENC			
Hip re AHP X	710.6	710.6	728.2	→	27.977	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	27.599	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_HIP_X	27.977	in
POSTURE_DHM3_EYE_X	27.599	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

124

Test #3: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

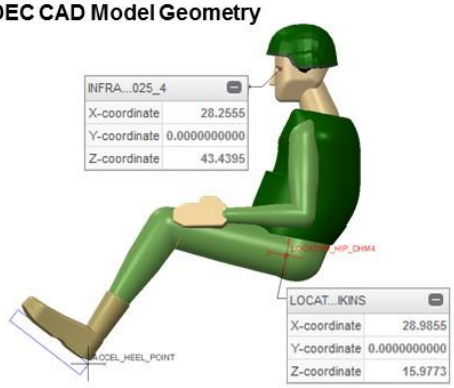
	ACU	PPE	ENC			
Hip re AHP X	736.2	736.2	753.8	→	28.985	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	28.255	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.986	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	28.256	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

125

Test #3: Longest Torso Male

UMTRI Spreadsheet Calculations*

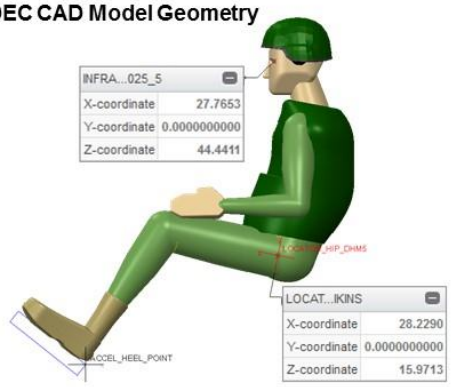
	ACU	PPE	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.229	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	27.765	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.229	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	27.765	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry



Side View

Front View

126

Test #3: Longest Legs Male

UMTRI Spreadsheet Calculations*

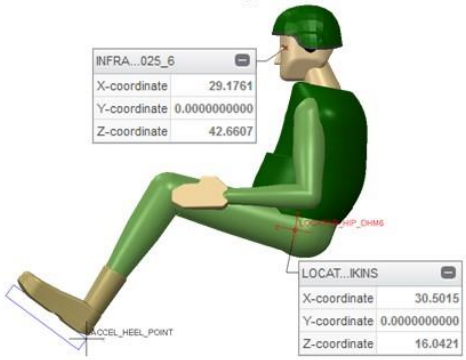
	ACU	PPE	ENC			
Hip re AHP X	774.7	774.7	792.3	→	30.501	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	29.176	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.502	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	29.176	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

127

Test #3: Large Overall Male

UMTRI Spreadsheet Calculations*

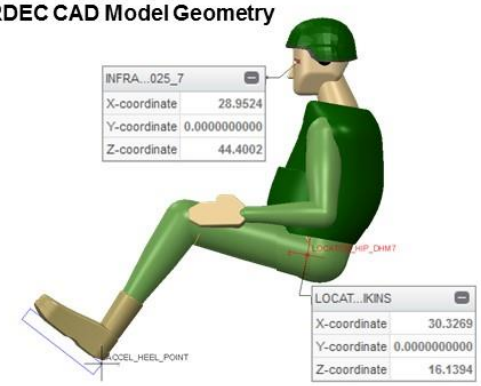
	ACU	PPE	ENC			
Hip re AHP X	770.3	770.3	787.9	→	30.327	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	28.952	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.327	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	28.952	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

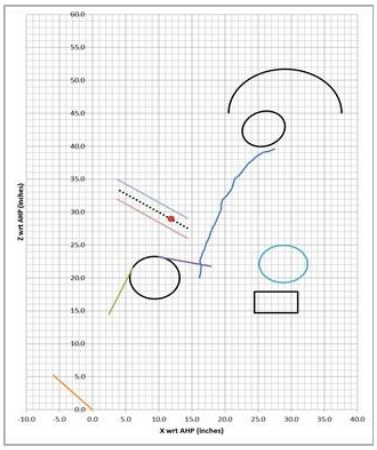
128

10.7.4 TEST #4 – VARY SWP IN FORE-AFT (X) DIRECTION

Test #4: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**11.8**	29.0	No	**SAE J826**

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

129

Test #4: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	11.800	in	11.800	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	27.690	in	27.691	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.279	in	16.279	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.148	deg	16.145	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.346	deg	26.350	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	25.812	in	25.812	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.637	in	42.637	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.056	in	29.056	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	45.054	in	45.055	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	9.382	in	9.382	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.458	in	7.458	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	20.033	in	20.033	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.511	in	7.513	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.452	in	6.452	in	0.000	in
KNEE_SHIN_ANGLE	26.682	deg	26.682	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	21.559	in	21.558	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.583	in	33.583	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	28.790	in	28.790	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	22.123	in	22.123	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

130

Test #4: Surrogate Steering Wheel

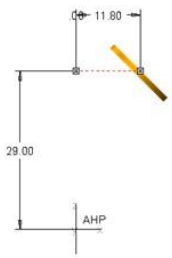
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	11.800	29.000

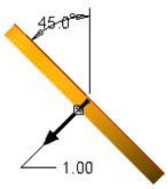
TARDEC CAD Model Calculations

STEERING_WHEEL_X	11.800	in
STEERING_WHEEL_Z	29.000	in

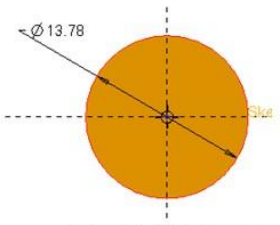
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

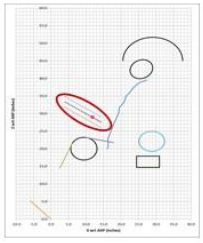
Side View **Steering Wheel Geometry**

131

Test #4: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

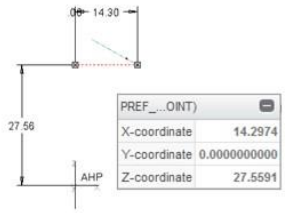
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



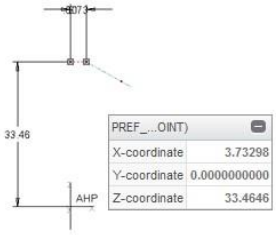
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



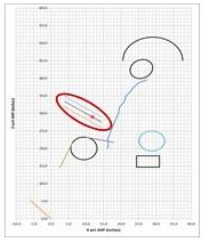
Preference Line Endpoint, Max

132

Test #4: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

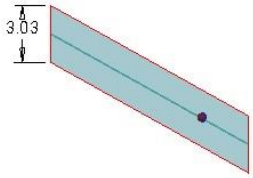
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



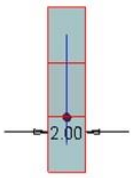
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

*Given value, not calculated

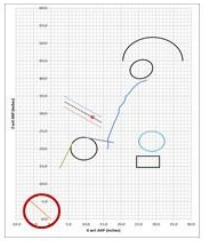
133

Test #4: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA) 41.438 deg

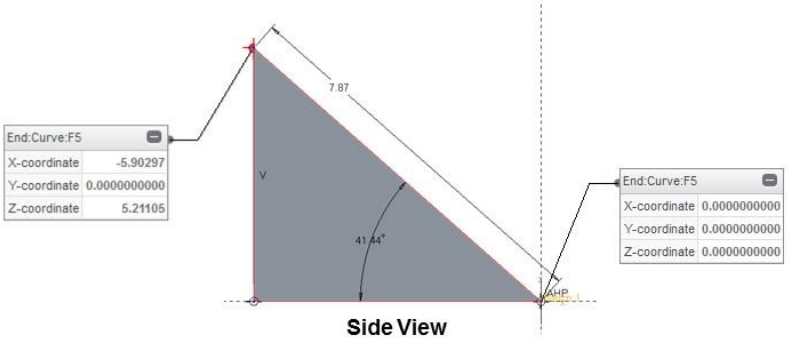
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

TARDEC CAD Model Geometry



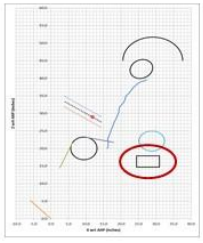
Side View

134

Test #4: Seat Track Travel Range

UMTRI Spreadsheet Calculations

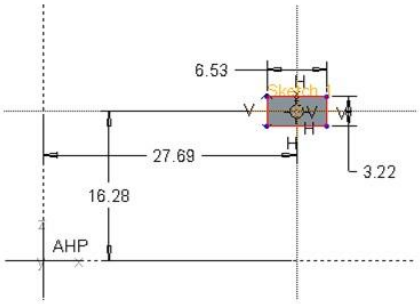
Center of Travel (X)	27.690	in
Center of Travel (Z)	16.279	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.223	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	27.691	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.279	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 11.8 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.7 in., Z = 16.3 in.)

135

Test #4: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	16.148 deg
Rear of Range	26.346 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.145	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.350	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.7 in., Z = 16.3 in.)

Seat Back Angle (wrt vertical): 16.1^{o} to 26.4^{o}

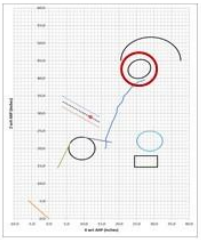
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

136

Test #4: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	25.812	1.280*	42.637
Left	25.812	-1.280*	42.637



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		25.812	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		42.637	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

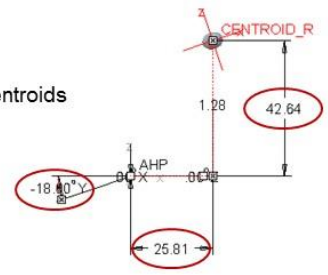
*Given value, not calculated

137

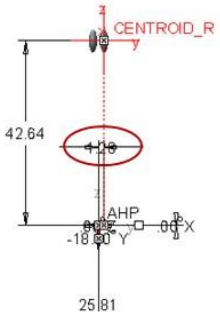
Test #4: Eyellipse (cont.)

TARDEC CAD Model Geometry

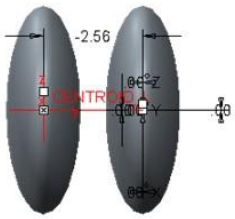
Centroids



Side View

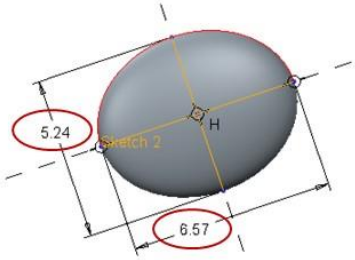


Rear View

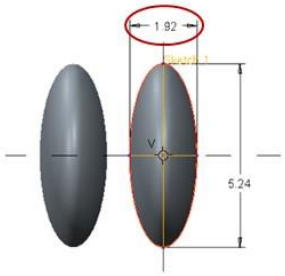


Rear View

Axis Lengths



Side View

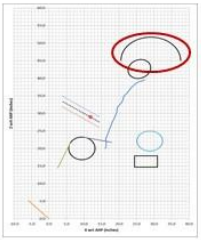


Rear View (Rotated)

Test #4: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	29.056	2.185*	45.054
Left	29.056	-2.185*	45.054



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.045	in
Axis Length (Z)	→	13.292	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.292	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		29.056	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		45.055	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.048	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.296	in

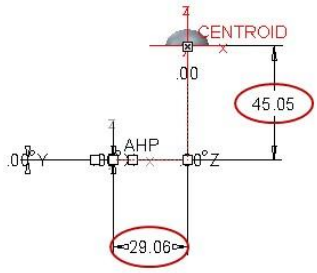
$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

*Given value, not calculated

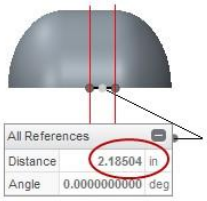
Test #4: Helmet Boundary (cont.)

TARDEC CAD Model Result

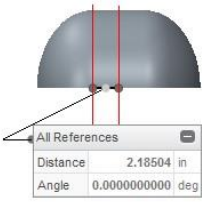
Centroids



Side View

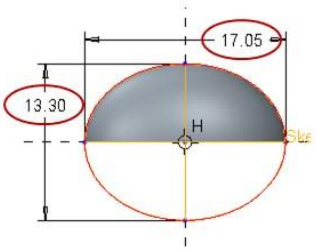


Rear View

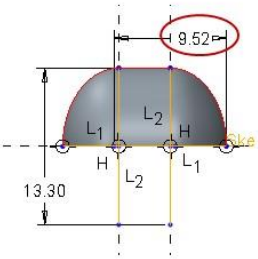


Rear View

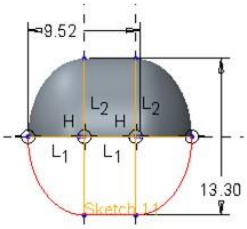
Axis Lengths



Side View



Rear View



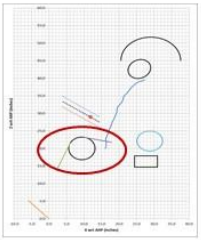
Rear View

140

Test #4: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	9.382	7.458	20.033
Left	9.382	-7.458	20.033



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.511	in
Axis Length (Z)	→	6.452	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.671	in
Axis Length (Z)	→	6.452	in
Leg Segment Angle wrt Vertical		26.682	deg
Thigh Segment Angle wrt Horizontal		10.322	deg

TARDEC CAD Model Calculations

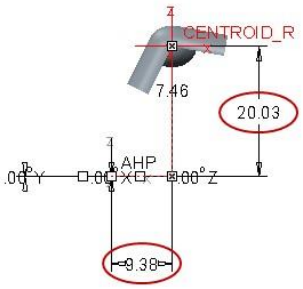
KNEE_CONTOUR_WEIGHTED_CENT_X		9.382	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		7.458	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		20.033	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.513	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	6.452	in
KNEE_SHIN_ANGLE		26.682	deg
KNEE_THIGH_ANGLE		10.322	deg

141

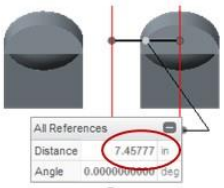
Test #4: Knee Boundary (cont.)

TARDEC CAD Model Result

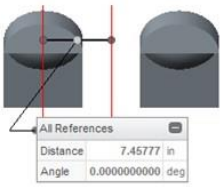
Centroids



Side View

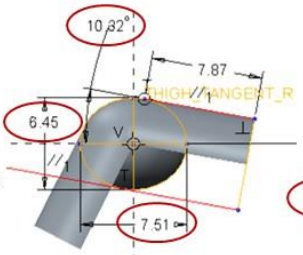


Rear View

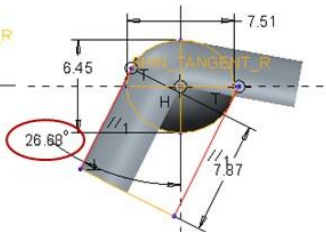


Rear View

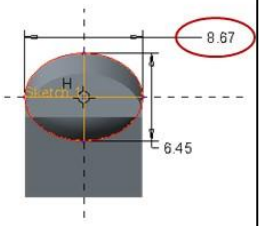
Axis Lengths
Shin/Thigh Angles



Side View



Side View



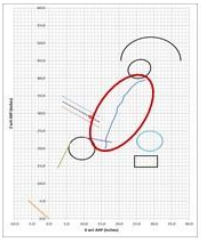
Rear View

142

Test #4: Torso Boundary (PPE)

UMTRI Spreadsheet Calculations

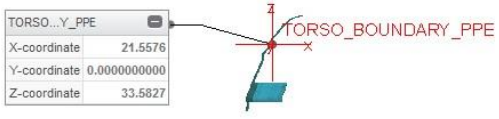
Mean Reference Point	X (in)	Z (in)
PPE	21.559	33.583
ENC	14.593	28.051



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	21.558	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.583	in

TARDEC CAD Model Geometry



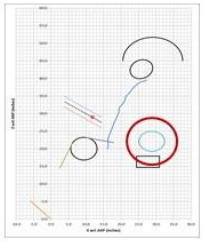
Side View

143

Test #4: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	28.790	12.353	22.123
Left	28.790	-12.353	22.123



Side View of Elbow Contours (X, Z)		
Axis Length (X)	→	7.303 in
Axis Length (Z)	→	5.665 in
Rear View of Elbow Contours (Y, Z)		
Axis Length (Y)	→	3.424 in
Axis Length (Z)	→	5.665 in

TARDEC CAD Model Calculations

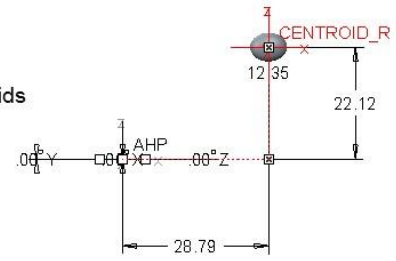
ELBOW_WEIGHTED_CENT_X		28.790	in
ELBOW_WEIGHTED_CENT_Y		12.353	in
ELBOW_WEIGHTED_CENT_Z		22.123	in
ELBOW_X_AXIS_LENGTH	→	7.305	in
ELBOW_Y_AXIS_LENGTH	→	3.425	in
ELBOW_Z_AXIS_LENGTH	→	5.668	in

144

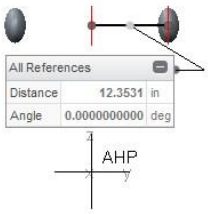
Test #4: Elbow Boundary (cont.)

TARDEC CAD Model Result

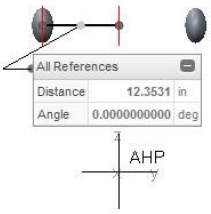
Centroids



Side View

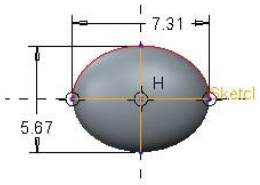


Rear View

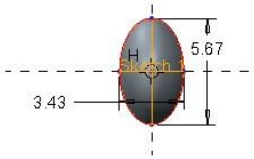


Rear View

Axis Lengths



Side View



Rear View

145

Test #4: Change SWP and HARP Tool

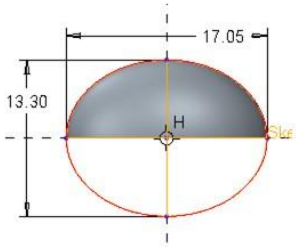
Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**11.8**	29.0	No	**SAE J826**

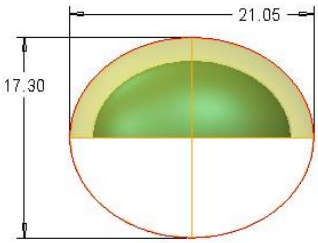
Clearance (2.0 inches), Shown in Yellow

TARDEC CAD Model

146

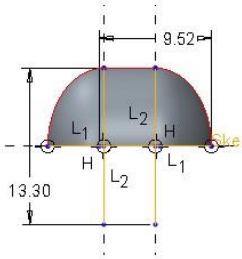
Test #4: Clearance, Helmet Boundary

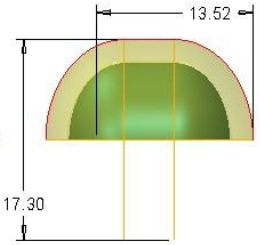


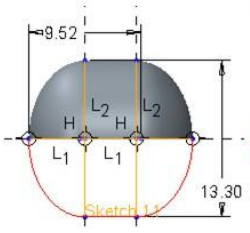


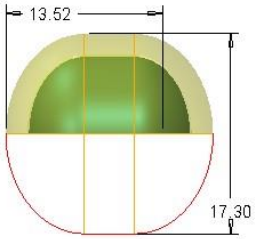
$$Sample\ Calculation: \frac{1}{2}\,(21.048\,in. - 17.048\,in.) = 2.000\,in.\,clearance$$

Side View





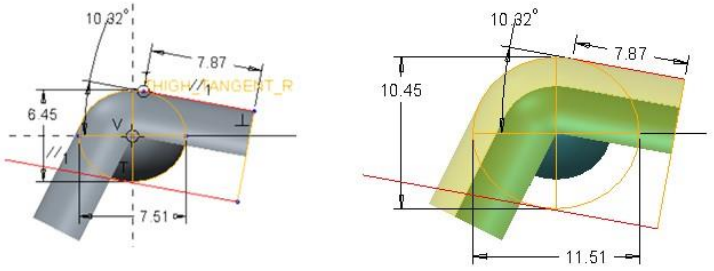




Rear View

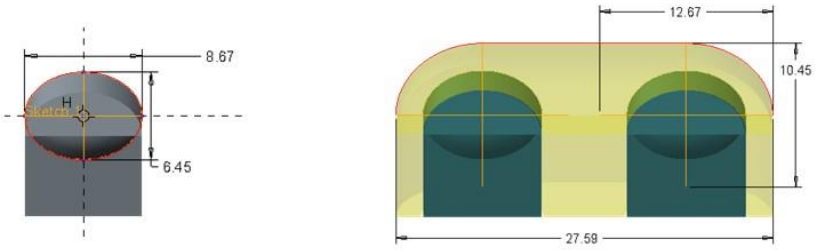
147

Test #4: Clearance, Knee Boundary



Sample Calculation: $\frac{1}{2}(10.452\,in. - 6.452\,in.) = 2.000\,in.\,clearance$

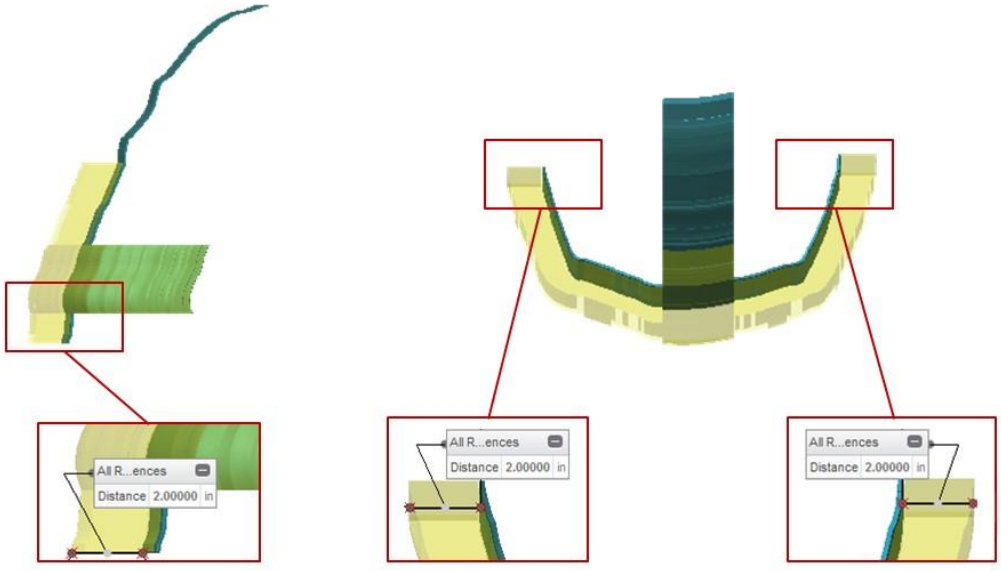
Side View



Rear View

148

Test #4: Clearance, Torso Boundary (PPE)



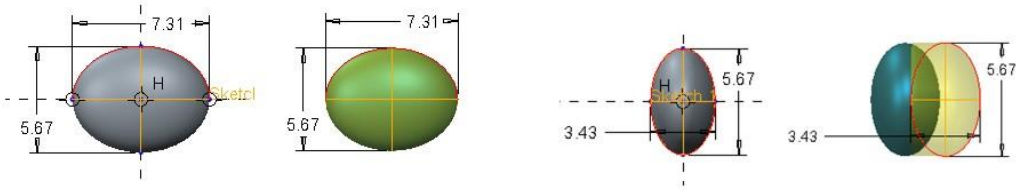
Side View **Top View**

149

Test #4: Clearance, Elbow Boundary

Sample Calculation: $14.353\ in. - 12.353\ in. = \ 2.000\ in.\ clearance$

Rear View



Side View **Rear View**

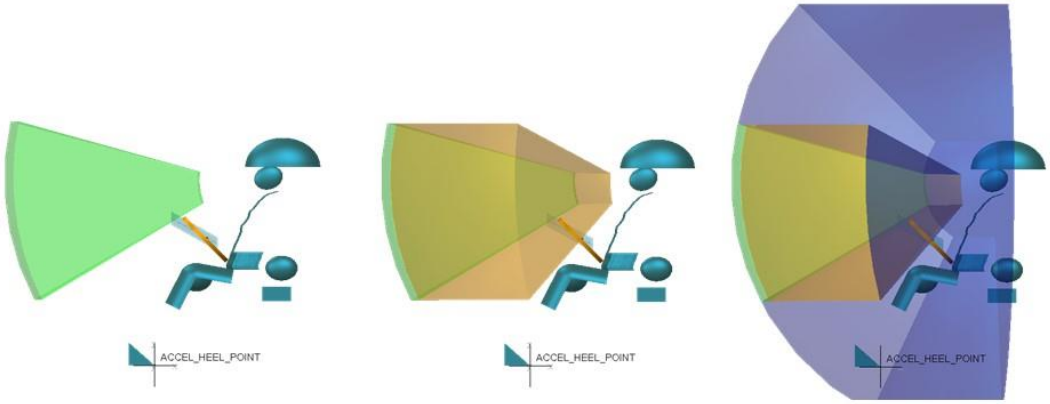
150

Test #4: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**11.8**	29.0	No	**SAE J826**

Vision Zones

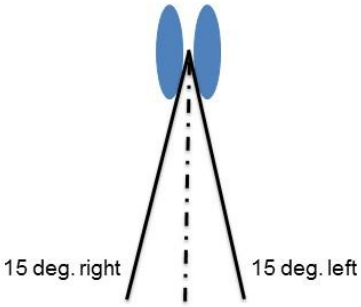
Vison zones are constructed geometrically; no calculations are involved.



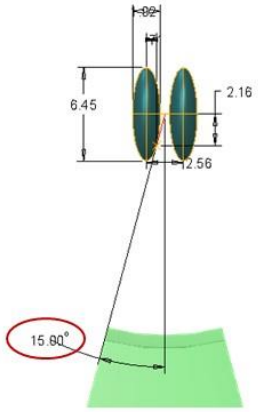
Primary Zone Secondary Zone Tertiary Zone

151

Test #4: Primary Vision Zone



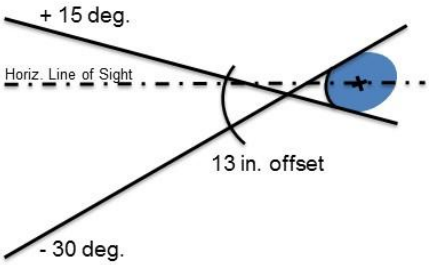
Top View



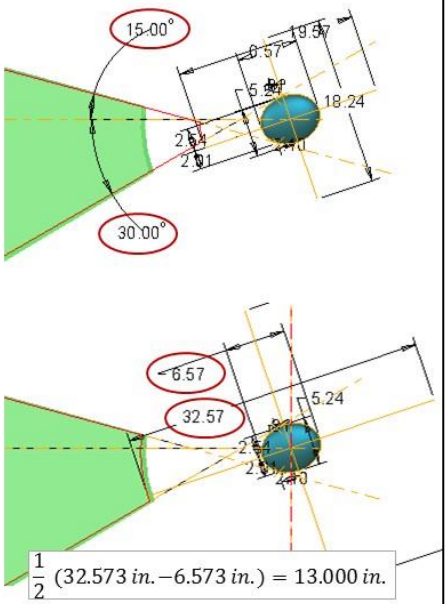
Intent | CAD Implementation

152

Test #4: Primary Vision Zone (cont.)



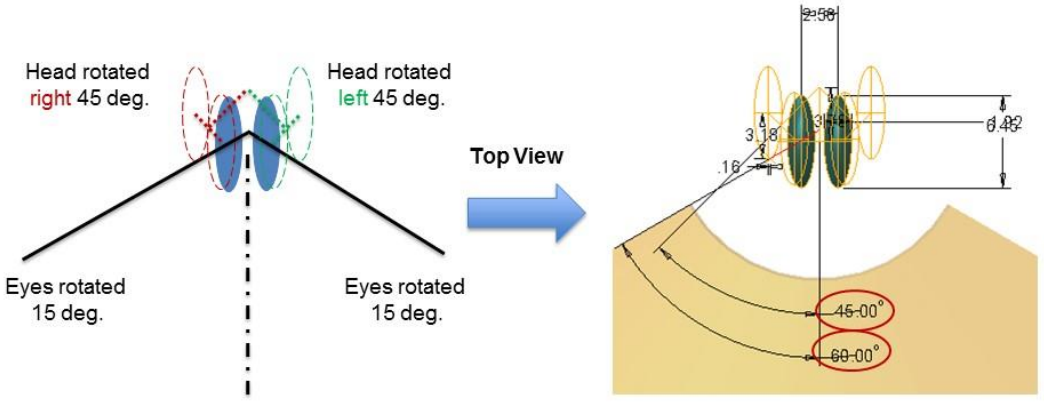
Side View



Intent | CAD Implementation

153

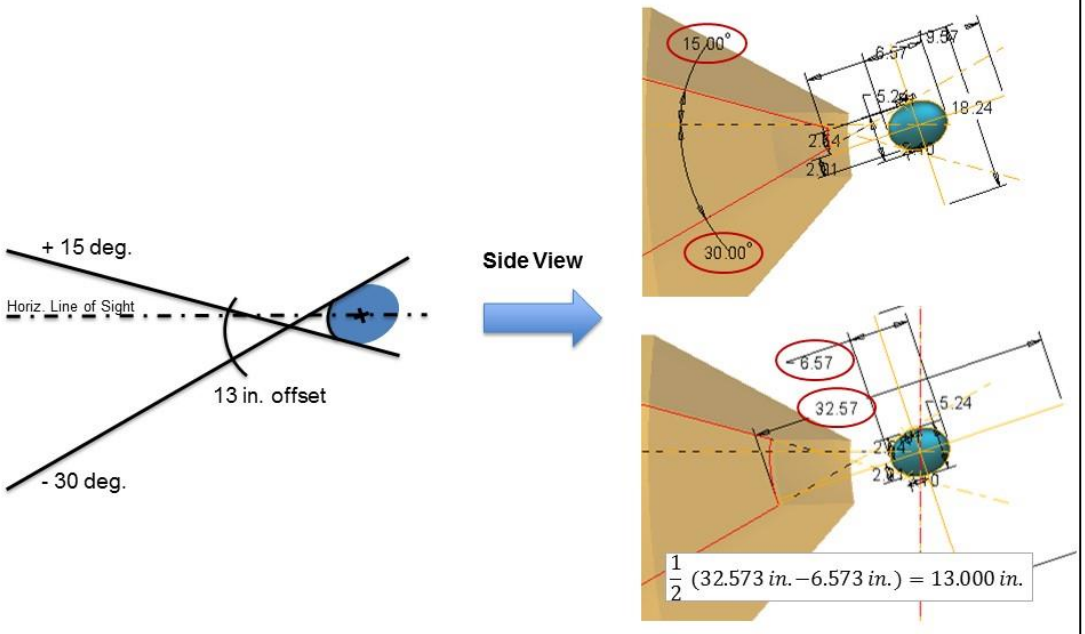
Test #4: Secondary Vision Zone



Intent CAD Implementation

154

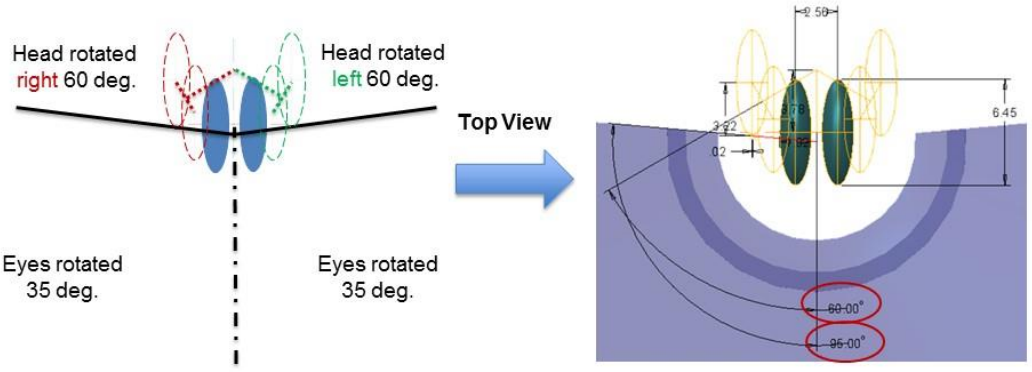
Test #4: Secondary Vision Zone (cont.)



Intent CAD Implementation

155

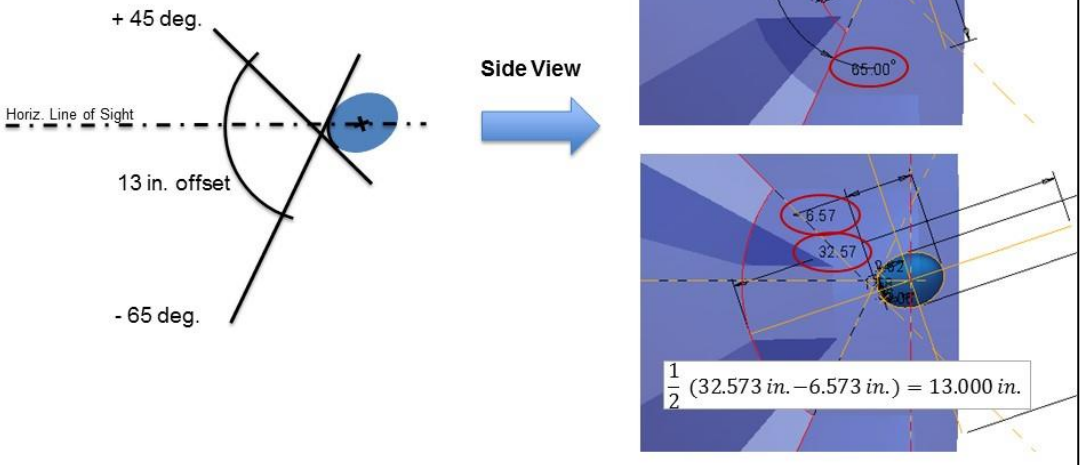
Test #4: Tertiary Vision Zone



Intent **CAD Implementation**

156

Test #4: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

157

Test #4: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**11.8**	29.0	No	**SAE J826**

Boundary Manikin Posture and Position

TARDEC CAD Model

158

Test #4: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	22.881	in	22.881	in	0.000	in
POSTURE_DHM1_HIP_Z	15.992	in	15.992	in	0.000	in
POSTURE_DHM1_EYE_X	24.036	in	24.036	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.003	in	25.003	in	0.000	in
POSTURE_DHM2_HIP_Z	16.102	in	16.102	in	0.000	in
POSTURE_DHM2_EYE_X	25.286	in	25.286	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	27.199	in	27.199	in	0.000	in
POSTURE_DHM3_HIP_Z	16.101	in	16.101	in	0.000	in
POSTURE_DHM3_EYE_X	26.695	in	26.695	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	28.207	in	28.207	in	0.000	in
POSTURE_DHM4_HIP_Z	16.090	in	16.090	in	0.000	in
POSTURE_DHM4_EYE_X	27.351	in	27.351	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	27.451	in	27.450	in	0.000	in
POSTURE_DHM5_HIP_Z	16.084	in	16.084	in	0.000	in
POSTURE_DHM5_EYE_X	26.861	in	26.861	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	29.723	in	29.723	in	0.000	in
POSTURE_DHM6_HIP_Z	16.155	in	16.155	in	0.000	in
POSTURE_DHM6_EYE_X	28.271	in	28.272	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	29.548	in	29.548	in	0.000	in
POSTURE_DHM7_HIP_Z	16.252	in	16.252	in	0.000	in
POSTURE_DHM7_EYE_X	28.048	in	28.048	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

159

Test #4: Small Overall Female

UMTRI Spreadsheet Calculations*

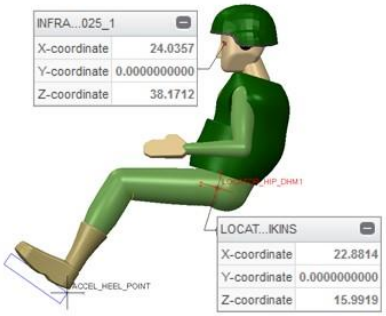
	ACU	PPE	ENC			
Hip re AHP X	581.2	581.2	598.8	→	22.881	in
Hip re AHP Z	406.2	406.2	406.2	→	15.992	in
Eye re AHP X	646.5	610.5	607.5	→	24.036	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	22.881	in
POSTURE_DHM1_HIP_Z	15.992	in
POSTURE_DHM1_EYE_X	24.036	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

160

Test #4: Small Overall Male

UMTRI Spreadsheet Calculations*

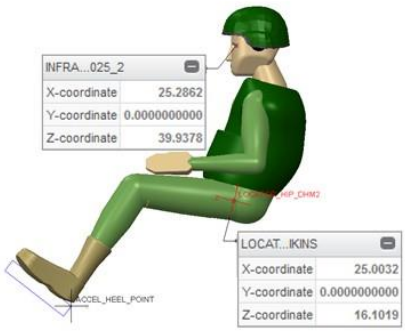
	ACU	PPE	ENC			
Hip re AHP X	635.1	635.1	652.7	→	25.003	in
Hip re AHP Z	409.0	409.0	409.0	→	16.102	in
Eye re AHP X	678.3	642.3	639.3	→	25.286	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.003	in
POSTURE_DHM2_HIP_Z	16.102	in
POSTURE_DHM2_EYE_X	25.286	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

161

Test #4: Average Size Male

UMTRI Spreadsheet Calculations*

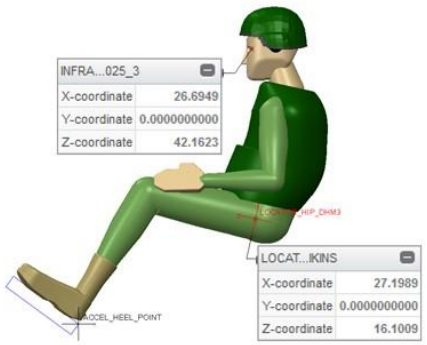
	ACU	PPE	ENC			
Hip re AHP X	690.9	690.9	708.5	→	27.199	in
Hip re AHP Z	409.0	409.0	409.0	→	16.101	in
Eye re AHP X	714.1	678.1	675.1	→	26.695	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	27.199	in
POSTURE_DHM3_HIP_Z	16.101	in
POSTURE_DHM3_EYE_X	26.695	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

162

Test #4: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

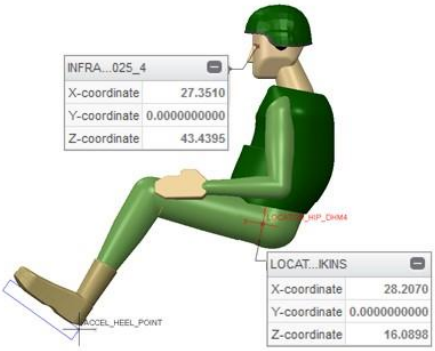
	ACU	PPE	ENC			
Hip re AHP X	716.5	716.5	734.1	→	28.207	in
Hip re AHP Z	408.7	408.7	408.7	→	16.090	in
Eye re AHP X	730.7	694.7	691.7	→	27.351	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.207	in
POSTURE_DHM4_HIP_Z	16.090	in
POSTURE_DHM4_EYE_X	27.351	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

163

Test #4: Longest Torso Male

UMTRI Spreadsheet Calculations*

	ACU	PPE	ENC			
Hip re AHP X	697.2	697.2	714.8	→	27.451	in
Hip re AHP Z	408.5	408.5	408.5	→	16.084	in
Eye re AHP X	718.3	682.3	679.3	→	26.861	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	27.450	in
POSTURE_DHM5_HIP_Z	16.084	in
POSTURE_DHM5_EYE_X	26.861	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry

Side View

Front View

164

Test #4: Longest Legs Male

UMTRI Spreadsheet Calculations*

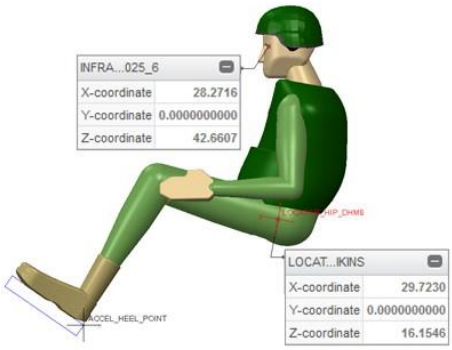
	ACU	PPE	ENC			
Hip re AHP X	755.0	755.0	772.6	→	29.723	in
Hip re AHP Z	410.3	410.3	410.3	→	16.155	in
Eye re AHP X	754.1	718.1	715.1	→	28.271	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	29.723	in
POSTURE_DHM6_HIP_Z	16.155	in
POSTURE_DHM6_EYE_X	28.272	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

165

Test #4: Large Overall Male

UMTRI Spreadsheet Calculations*

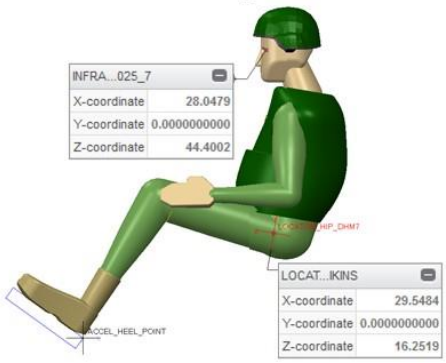
	ACU	PPE	ENC			
Hip re AHP X	750.5	750.5	768.1	→	29.548	in
Hip re AHP Z	412.8	412.8	412.8	→	16.252	in
Eye re AHP X	748.4	712.4	709.4	→	28.048	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	29.548	in
POSTURE_DHM7_HIP_Z	16.252	in
POSTURE_DHM7_EYE_X	28.048	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

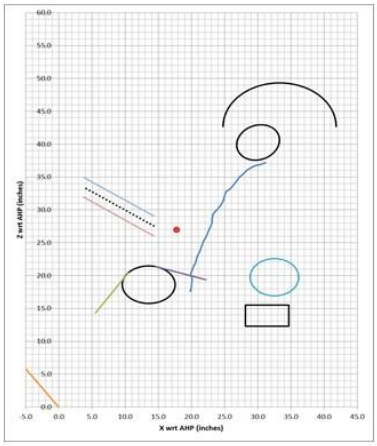
166

10.7.5 TEST #5 – VARY SWP IN FORE-AFT (X) AND VERTICAL (Z) DIRECTION

Test #5: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**17.7**	**27.0**	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

167

Test #5: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	17.700	in	17.700	in	0.000	in
STEERING_WHEEL_Z	27.000	in	27.000	in	0.000	in
Steering Wheel Preference Line	**UMTRI Value**		**TARDEC Value**		**Difference**	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone	**UMTRI Value**		**TARDEC Value**		**Difference**	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)	**UMTRI Value**		**TARDEC Value**		**Difference**	
ACCEL_PEDAL_PLANE_ANG	49.214	deg	49.214	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.144	in	-5.144	in	0.000	in
BOFRP (Z)	5.962	in	5.962	in	0.000	in
Seat Track Travel Range	**UMTRI Value**		**TARDEC Value**		**Difference**	
SEAT_POSITION_CTR_OF_TRAVEL_X	31.393	in	31.394	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	13.908	in	13.908	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.222	in	3.223	in	0.001	in
Seat Back Angle	**UMTRI Value**		**TARDEC Value**		**Difference**	
SEAT_BACK_ANGLE_LOWER_QUANTILE	17.572	deg	17.568	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.770	deg	27.774	deg	0.004	deg
Eyellipse	**UMTRI Value**		**TARDEC Value**		**Difference**	
EYELLIPSE_CENTROID_X	30.025	in	30.025	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	40.266	in	40.266	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	33.269	in	33.269	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	42.683	in	42.683	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.045	in	17.048	in	0.003	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.292	in	13.296	in	0.004	in
Knee Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
KNEE_CONTOUR_WEIGHTED_CENT_X	13.535	in	13.535	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.087	in	7.087	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	18.619	in	18.619	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.969	in	7.971	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	5.704	in	5.704	in	0.000	in
KNEE_SHIN_ANGLE	38.906	deg	38.906	deg	0.000	deg
KNEE_THIGH_ANGLE	14.742	deg	14.742	deg	0.000	deg
Torso Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
TORSO_WEIGHTED_REF_PT_PPE_X	25.261	in	25.260	in	0.001	in
TORSO_WEIGHTED_REF_PT_PPE_Z	31.211	in	31.211	in	0.000	in
Elbow Boundary	**UMTRI Value**		**TARDEC Value**		**Difference**	
ELBOW_WEIGHTED_CENT_X	32.493	in	32.493	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	12.353	in	12.353	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	19.751	in	19.751	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

168

Test #5: Surrogate Steering Wheel

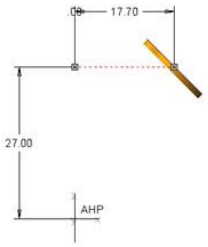
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	17.700	27.000

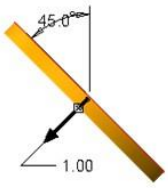
TARDEC CAD Model Calculations

STEERING_WHEEL_X	17.700	in
STEERING_WHEEL_Z	27.000	in

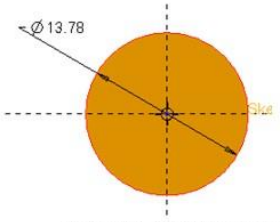
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

Side View **Steering Wheel Geometry**

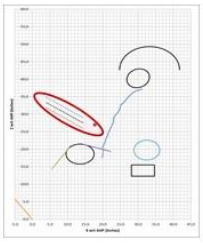
Unclassified // For Official Use Only

169

Test #5: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

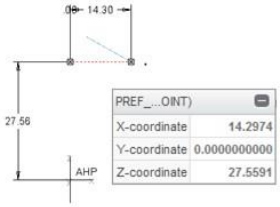
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



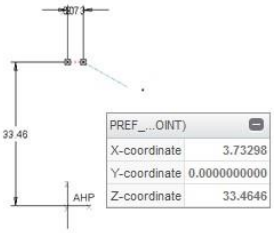
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



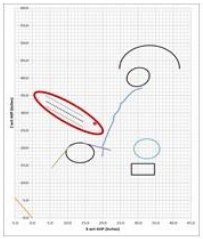
Preference Line Endpoint, Max

170

Test #5: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

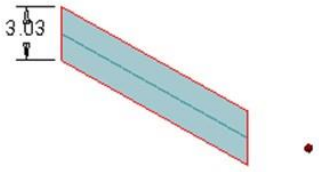
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



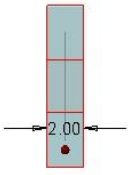
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

*Given value, not calculated

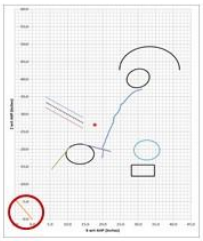
171

Test #5: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA) 49.214 deg

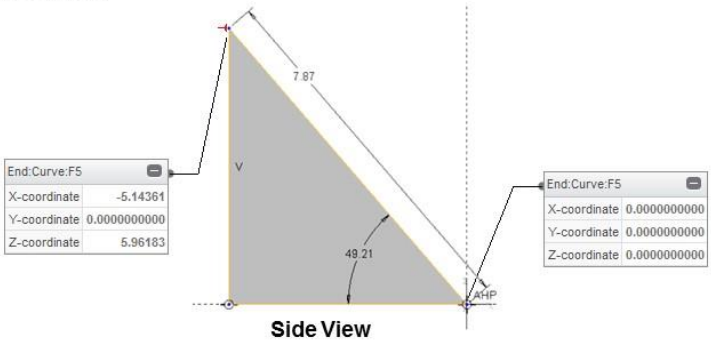
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.144	5.962



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	49.214	deg

TARDEC CAD Model Geometry



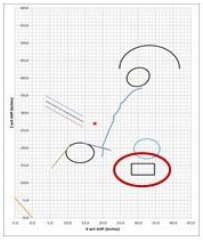
Side View

172

Test #5: Seat Track Travel Range

UMTRI Spreadsheet Calculations

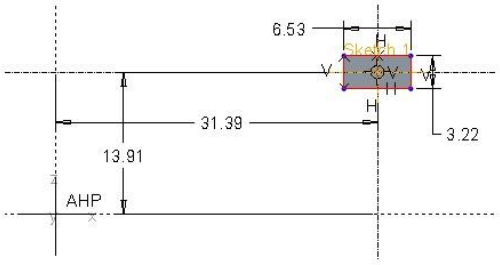
Center of Travel (X)	31.393	in
Center of Travel (Z)	13.908	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.222	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	31.394	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	13.908	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 17.7 in.
Steering Wheel Point, Z (wrt AHP): 27.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 31.4 in., Z = 13.9 in.)

173

Test #5: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	17.572 deg
Rear of Range	27.770 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	17.568	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	27.774	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 31.4 in., Z = 13.9 in.)

Seat Back Angle (wrt vertical): 17.6^{o} to 27.8^{o}

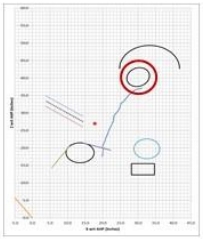
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

174

Test #5: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	30.025	1.280*	40.266
Left	30.025	-1.280*	40.266



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		30.025	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		40.266	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

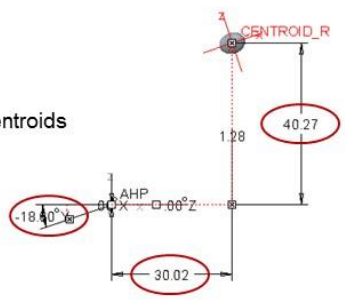
*Given value, not calculated

175

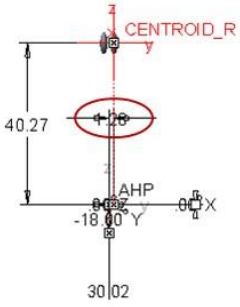
Test #5: Eyellipse (cont.)

TARDEC CAD Model Geometry

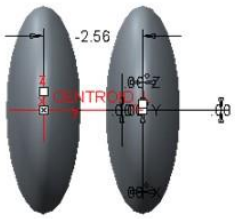
Centroids



Side View

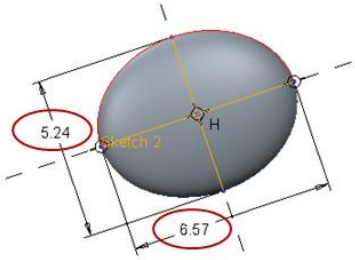


Rear View

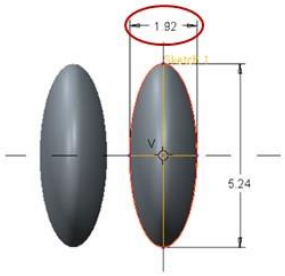


Rear View

Axis Lengths



Side View

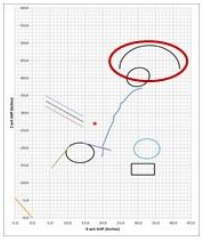


Rear View (Rotated)

Test #5: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	33.269	2.185*	42.683
Left	33.269	-2.185*	42.683



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.045	in
Axis Length (Z)	→	13.292	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.292	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		33.269	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		42.683	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.048	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.296	in

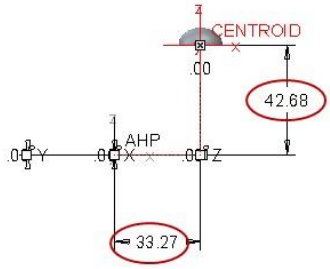
$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

*Given value, not calculated

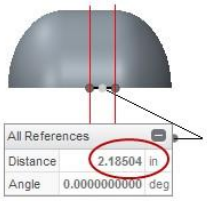
Test #5: Helmet Boundary (cont.)

TARDEC CAD Model Result

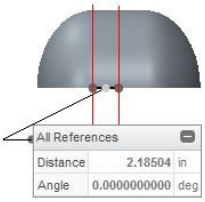
Centroids



Side View

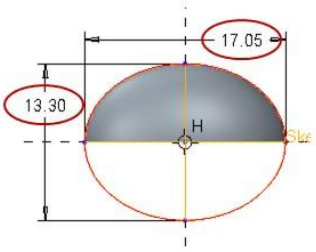


Rear View

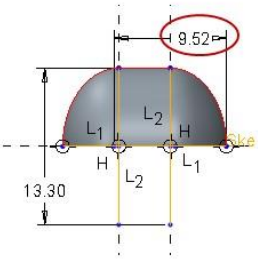


Rear View

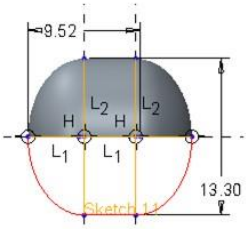
Axis Lengths



Side View



Rear View



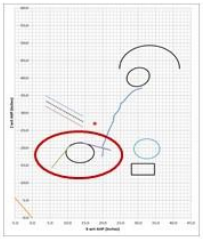
Rear View

178

Test #5: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	13.535	7.087	18.619
Left	13.535	-7.087	18.619



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.969	in
Axis Length (Z)	→	5.704	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.671	in
Axis Length (Z)	→	5.704	in
Leg Segment Angle wrt Vertical		38.906	deg
Thigh Segment Angle wrt Horizontal		14.742	deg

TARDEC CAD Model Calculations

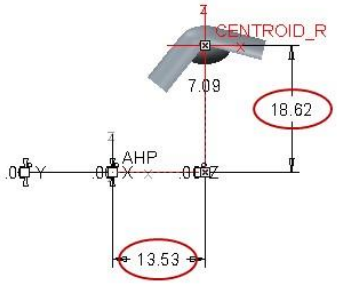
KNEE_CONTOUR_WEIGHTED_CENT_X		13.535	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		7.087	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		18.619	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.971	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	5.704	in
KNEE_SHIN_ANGLE		38.906	deg
KNEE_THIGH_ANGLE		14.742	deg

179

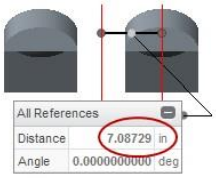
Test #5: Knee Boundary (cont.)

TARDEC CAD Model Result

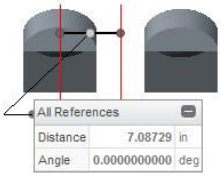
Centroids



Side View

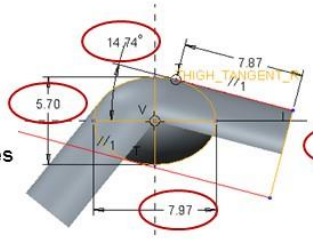


Rear View

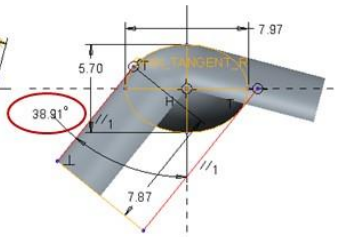


Rear View

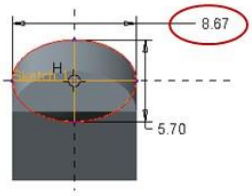
Axis Lengths
Shin/Thigh Angles



Side View



Side View



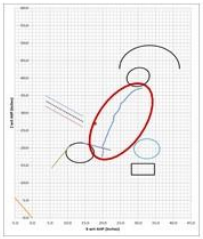
Rear View

180

Test #5: Torso Boundary (PPE)

UMTRI Spreadsheet Calculations

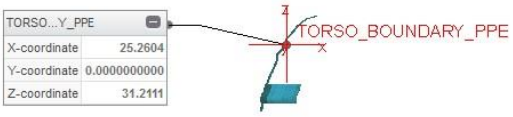
Mean Reference Point	X (in)	Z (in)
PPE	25.261	31.211
ENC	18.296	25.679



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	25.260	in
TORSO_WEIGHTED_REF_PT_PPE_Z	31.211	in

TARDEC CAD Model Geometry



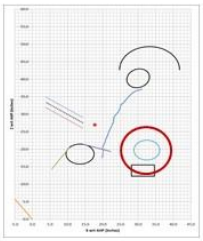
Side View

181

Test #5: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	32.493	12.353	19.751
Left	32.493	-12.353	19.751



Side View of Elbow Contours (X, Z)

Axis Length (X)	7.303 in
Axis Length (Z)	5.665 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	3.424 in
Axis Length (Z)	5.665 in

TARDEC CAD Model Calculations

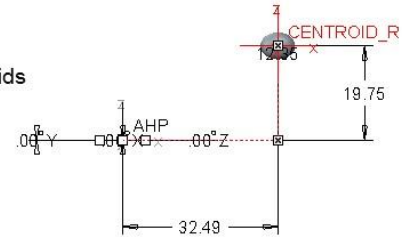
ELBOW_WEIGHTED_CENT_X	32.493	in
ELBOW_WEIGHTED_CENT_Y	12.353	in
ELBOW_WEIGHTED_CENT_Z	19.751	in
ELBOW_X_AXIS_LENGTH	7.305	in
ELBOW_Y_AXIS_LENGTH	3.425	in
ELBOW_Z_AXIS_LENGTH	5.668	in

182

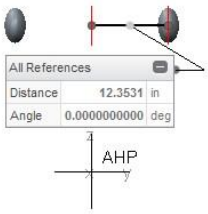
Test #5: Elbow Boundary (cont.)

TARDEC CAD Model Result

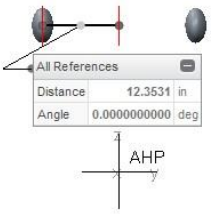
Centroids



Side View

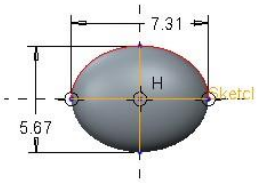


Rear View

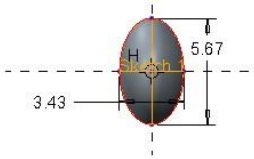


Rear View

Axis Lengths



Side View



Rear View

183

Test #5: Vary Steering Wheel Point (SWP)

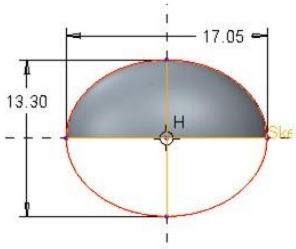
Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**17.7**	**27.0**	No	SAE J826

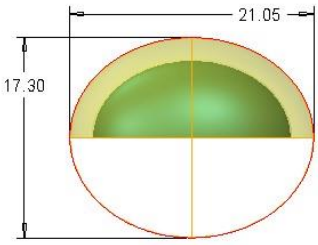
Clearance (2.0 inches), Shown in Yellow

TARDEC CAD Model

184

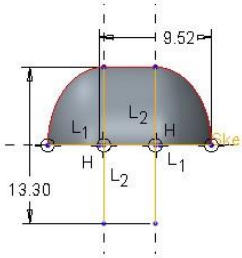
Test #5: Clearance, Helmet Boundary

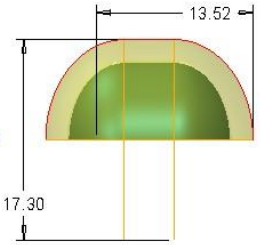


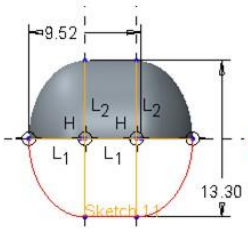


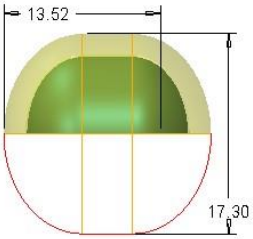
$$Sample\ Calculation: \frac{1}{2}\,(21.048\,in. - 17.048\,in.) = 2.000\,in.\,clearance$$

Side View





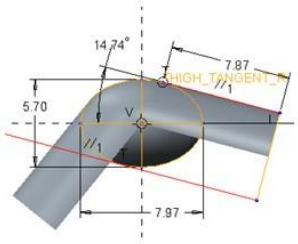


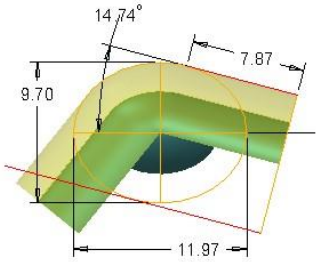


Rear View

185

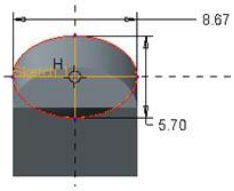
Test #5: Clearance, Knee Boundary

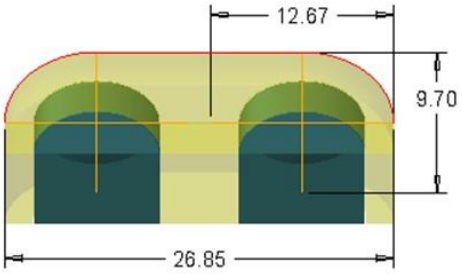




$$Sample\ Calculation: \frac{1}{2}\ (9.704\ in. - 5.704\ in.) = 2.000\ in. clearance$$

Side View

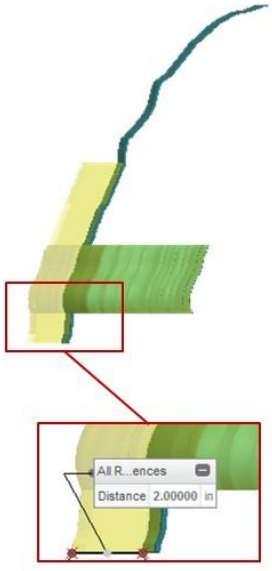


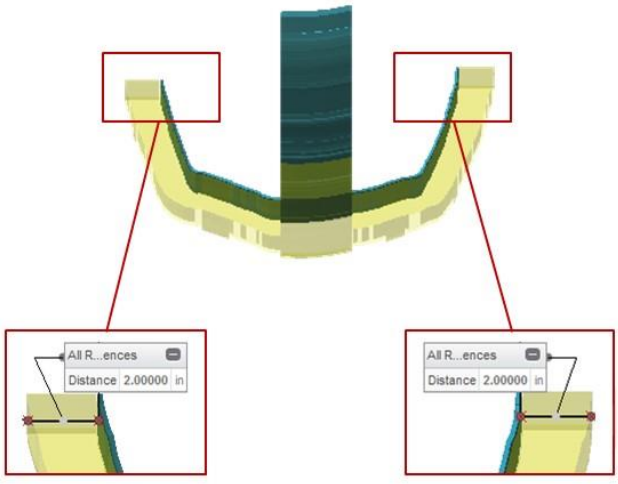


Rear View

186

Test #5: Clearance, Torso Boundary (PPE)





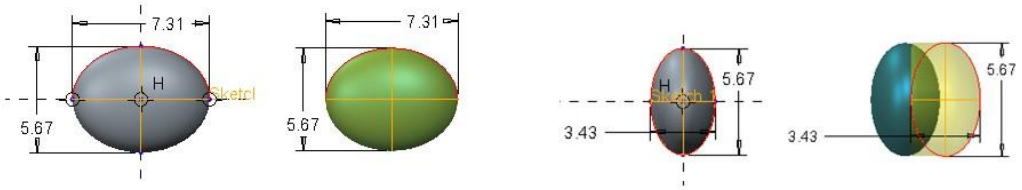
Side View **Top View**

187

Test #5: Clearance, Elbow Boundary

Sample Calculation: 14.353 *in.* − 12.353 *in.* = 2.000 *in. clearance*

Rear View



Side View **Rear View**

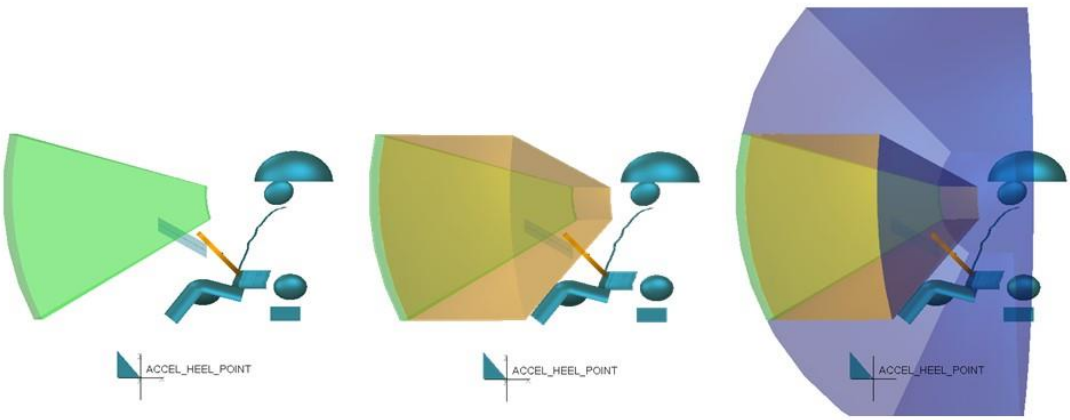
188

Test #5: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	**17.7**	**27.0**	No	SAE J826

Vision Zones

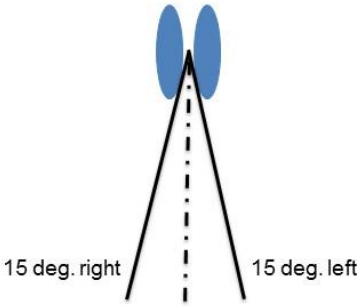
Vison zones are constructed geometrically; no calculations are involved.



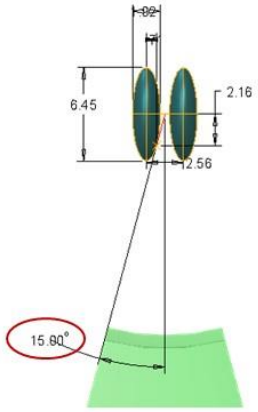
Primary Zone Secondary Zone Tertiary Zone

189

Test #5: Primary Vision Zone



Top View

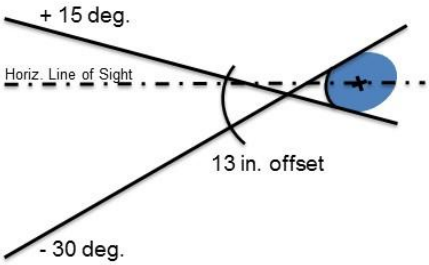


Intent

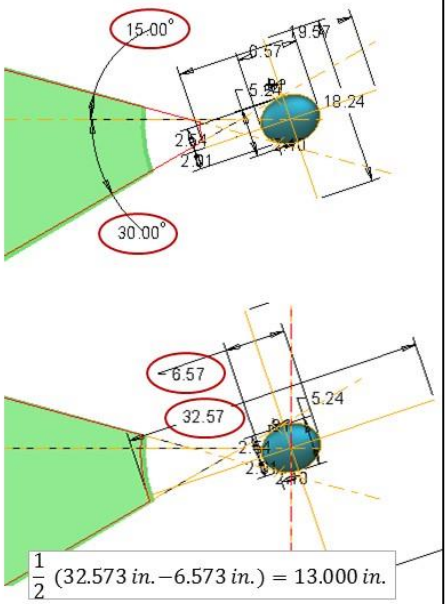
CAD Implementation

190

Test #5: Primary Vision Zone (cont.)



Side View

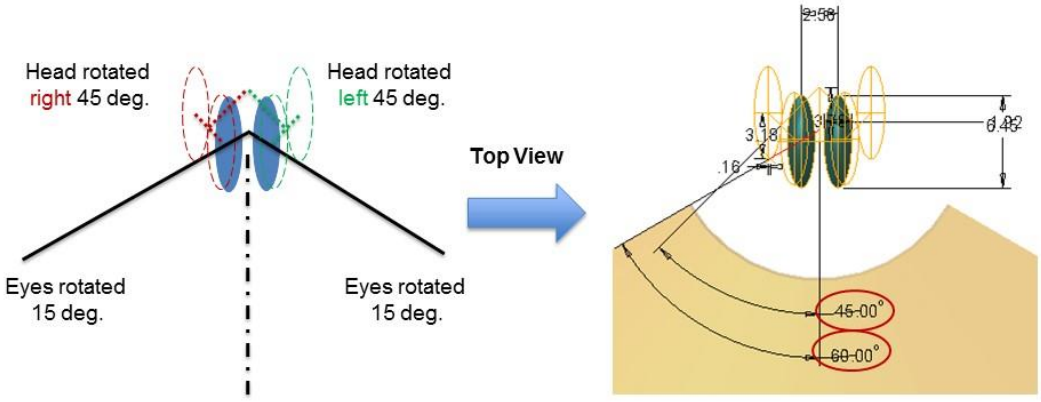


Intent

CAD Implementation

191

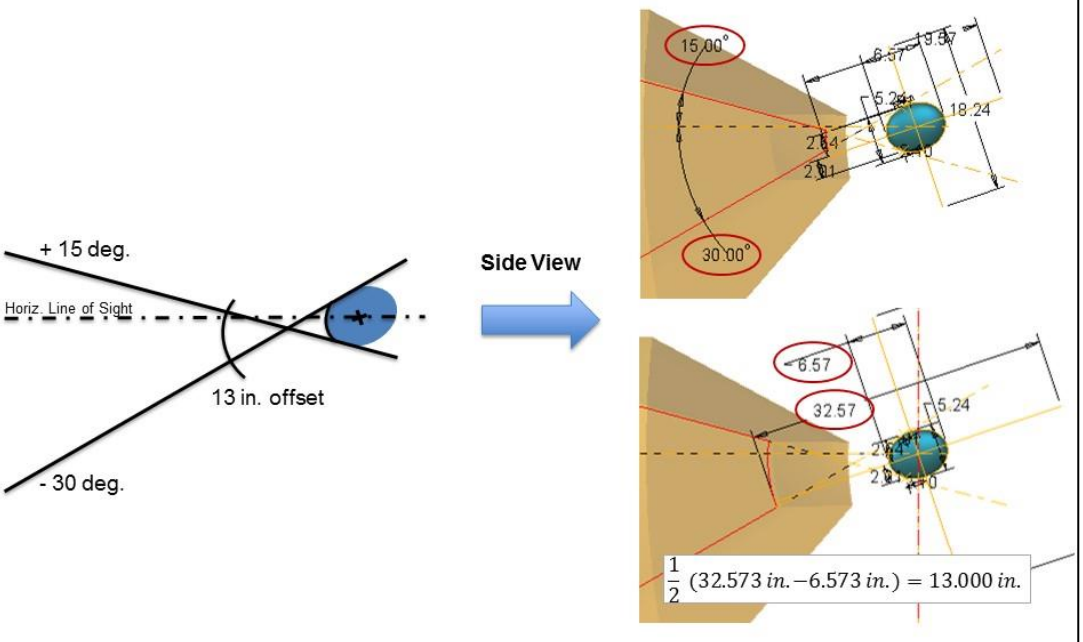
Test #5: Secondary Vision Zone



Intent **CAD Implementation**

192

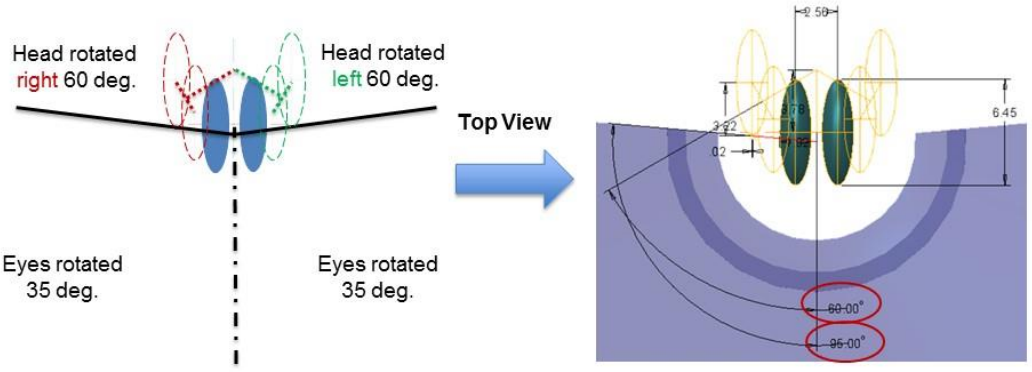
Test #5: Secondary Vision Zone (cont.)



Intent **CAD Implementation**

193

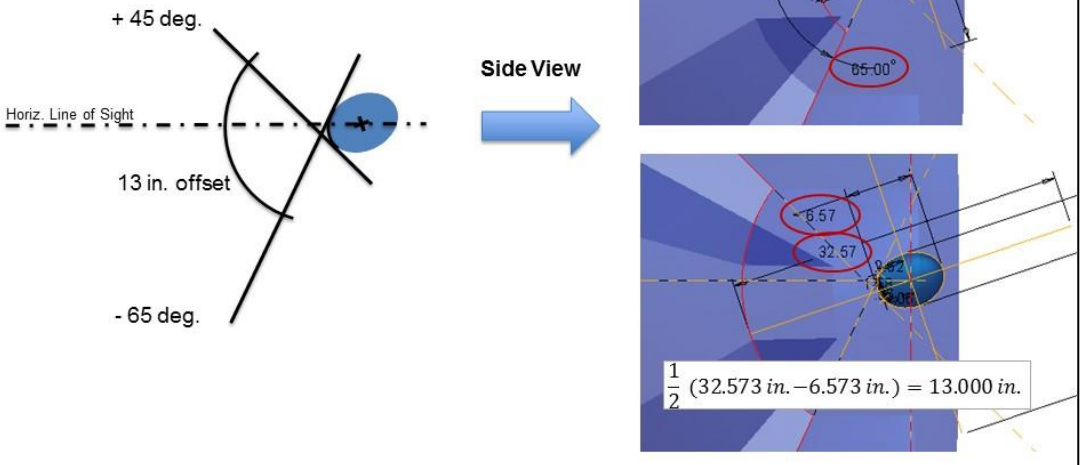
Test #5: Tertiary Vision Zone



Intent **CAD Implementation**

194

Test #5: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

195

Test #5: Vary Steering Wheel Point (SWP)

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	PPE	17.7	27.0	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

196

Test #5: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	26.711	in	26.711	in	0.000	in
POSTURE_DHM1_HIP_Z	13.602	in	13.602	in	0.000	in
POSTURE_DHM1_EYE_X	28.293	in	28.293	in	0.000	in
POSTURE_DHM1_EYE_Z	36.111	in	36.111	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	28.833	in	28.833	in	0.000	in
POSTURE_DHM2_HIP_Z	13.712	in	13.712	in	0.000	in
POSTURE_DHM2_EYE_X	29.543	in	29.543	in	0.000	in
POSTURE_DHM2_EYE_Z	37.878	in	37.878	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	31.029	in	31.028	in	0.000	in
POSTURE_DHM3_HIP_Z	13.711	in	13.711	in	0.000	in
POSTURE_DHM3_EYE_X	30.952	in	30.952	in	0.000	in
POSTURE_DHM3_EYE_Z	40.102	in	40.102	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	32.036	in	32.037	in	0.000	in
POSTURE_DHM4_HIP_Z	13.700	in	13.700	in	0.000	in
POSTURE_DHM4_EYE_X	31.608	in	31.608	in	0.000	in
POSTURE_DHM4_EYE_Z	41.380	in	41.380	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	31.280	in	31.280	in	0.000	in
POSTURE_DHM5_HIP_Z	13.694	in	13.694	in	0.000	in
POSTURE_DHM5_EYE_X	31.118	in	31.118	in	0.000	in
POSTURE_DHM5_EYE_Z	42.381	in	42.381	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	33.553	in	33.553	in	0.000	in
POSTURE_DHM6_HIP_Z	13.765	in	13.765	in	0.000	in
POSTURE_DHM6_EYE_X	32.529	in	32.529	in	0.000	in
POSTURE_DHM6_EYE_Z	40.601	in	40.601	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	33.378	in	33.378	in	0.000	in
POSTURE_DHM7_HIP_Z	13.862	in	13.862	in	0.000	in
POSTURE_DHM7_EYE_X	32.305	in	32.305	in	0.000	in
POSTURE_DHM7_EYE_Z	42.340	in	42.340	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

197

Test #5: Small Overall Female

UMTRI Spreadsheet Calculations*

	ACU	PPE	ENC			
Hip re AHP X	678.5	678.5	696.1	→	26.711	in
Hip re AHP Z	345.5	345.5	345.5	→	13.602	in
Eye re AHP X	754.6	718.6	715.6	→	28.293	in
Eye re AHP Z	917.2	917.2	917.2	→	36.111	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	26.711	in
POSTURE_DHM1_HIP_Z	13.602	in
POSTURE_DHM1_EYE_X	28.293	in
POSTURE_DHM1_EYE_Z	36.111	in

TARDEC CAD Model Geometry

Side View

Front View

198

Test #5: Small Overall Male

UMTRI Spreadsheet Calculations*

	ACU	PPE	ENC			
Hip re AHP X	732.4	732.4	750.0	→	28.833	in
Hip re AHP Z	348.3	348.3	348.3	→	13.712	in
Eye re AHP X	786.4	750.4	747.4	→	29.543	in
Eye re AHP Z	962.1	962.1	962.1	→	37.878	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	28.833	in
POSTURE_DHM2_HIP_Z	13.712	in
POSTURE_DHM2_EYE_X	29.543	in
POSTURE_DHM2_EYE_Z	37.878	in

TARDEC CAD Model Geometry

Side View

Front View

199

Test #5: Average Size Male

UMTRI Spreadsheet Calculations*

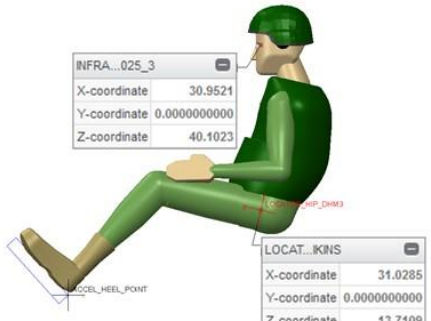
	ACU	PPE	ENC			
Hip re AHP X	788.1	788.1	805.7	→	31.029	in
Hip re AHP Z	348.3	348.3	348.3	→	13.711	in
Eye re AHP X	822.2	786.2	783.2	→	30.952	in
Eye re AHP Z	1018.6	1018.6	1018.6	→	40.102	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	31.028	in
POSTURE_DHM3_HIP_Z	13.711	in
POSTURE_DHM3_EYE_X	30.952	in
POSTURE_DHM3_EYE_Z	40.102	in

TARDEC CAD Model Geometry



Side View

Front View

200

Test #5: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

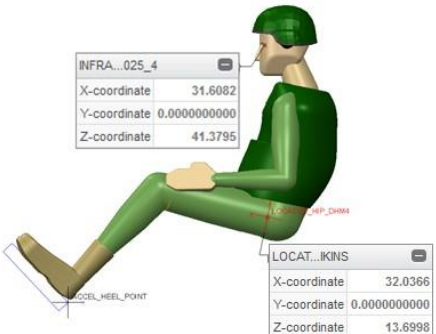
	ACU	PPE	ENC			
Hip re AHP X	813.7	813.7	831.3	→	32.036	in
Hip re AHP Z	348.0	348.0	348.0	→	13.700	in
Eye re AHP X	838.8	802.8	799.8	→	31.608	in
Eye re AHP Z	1051.0	1051.0	1051.0	→	41.380	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	32.037	in
POSTURE_DHM4_HIP_Z	13.700	in
POSTURE_DHM4_EYE_X	31.608	in
POSTURE_DHM4_EYE_Z	41.380	in

TARDEC CAD Model Geometry



Side View

Front View

201

Test #5: Longest Torso Male

UMTRI Spreadsheet Calculations*

	ACU	PPE	ENC			
Hip re AHP X	794.5	794.5	812.1	→	31.280	in
Hip re AHP Z	347.8	347.8	347.8	→	13.694	in
Eye re AHP X	826.4	790.4	787.4	→	31.118	in
Eye re AHP Z	1076.5	1076.5	1076.5	→	42.381	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	31.280	in
POSTURE_DHM5_HIP_Z	13.694	in
POSTURE_DHM5_EYE_X	31.118	in
POSTURE_DHM5_EYE_Z	42.381	in

TARDEC CAD Model Geometry

Side View

Front View

202

Test #5: Longest Legs Male

UMTRI Spreadsheet Calculations*

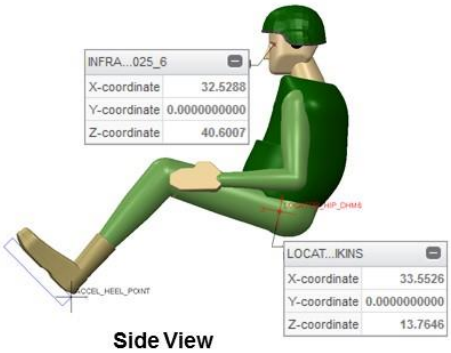
	ACU	PPE	ENC			
Hip re AHP X	852.2	852.2	869.8	→	33.553	in
Hip re AHP Z	349.6	349.6	349.6	→	13.765	in
Eye re AHP X	862.2	826.2	823.2	→	32.529	in
Eye re AHP Z	1031.3	1031.3	1031.3	→	40.601	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	33.553	in
POSTURE_DHM6_HIP_Z	13.765	in
POSTURE_DHM6_EYE_X	32.529	in
POSTURE_DHM6_EYE_Z	40.601	in

TARDEC CAD Model Geometry



Side View

Front View

203

Test #5: Large Overall Male

UMTRI Spreadsheet Calculations*

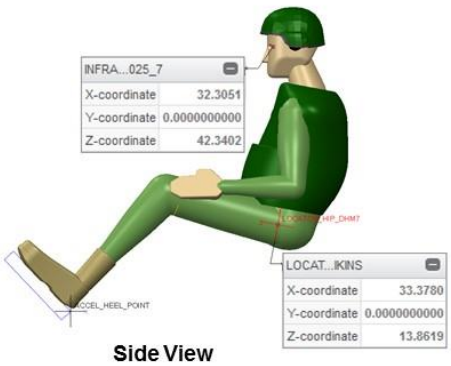
	ACU	PPE	ENC			
Hip re AHP X	847.8	847.8	865.4	→	33.378	in
Hip re AHP Z	352.1	352.1	352.1	→	13.862	in
Eye re AHP X	856.5	820.5	817.5	→	32.305	in
Eye re AHP Z	1075.4	1075.4	1075.4	→	42.340	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	33.378	in
POSTURE_DHM7_HIP_Z	13.862	in
POSTURE_DHM7_EYE_X	32.305	in
POSTURE_DHM7_EYE_Z	42.340	in

TARDEC CAD Model Geometry



Side View

Front View

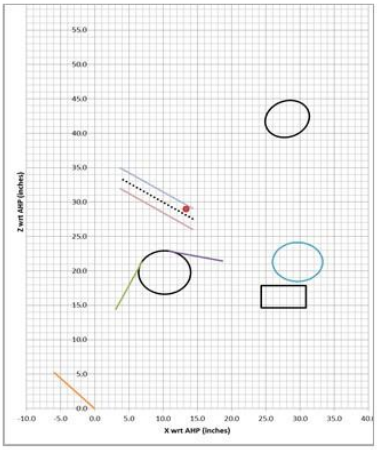
204

10.7.6 TEST #6 – VARY SWP IN FORE-AFT (X) AND VERTICAL (Z) DIRECTION AND ENSEMBLE

Test #6: Vary SWP and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	ACU	13.3	29.0	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

205

Test #6: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
SEAT_POSITION_CTR_OF_TRAVEL_X	27.602	in	27.603	in	0.001	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.244	in	16.244	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in	6.535	in	0.001	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in	3.223	in	0.001	in
Seat Back Angle						
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
EYELLIPSE_CENTROID_X	28.114	in	28.114	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.090	in	42.090	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.570	in	6.573	in	0.003	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.236	in	5.240	in	0.004	in

Helmet Boundary

The ACU ensemble does not include a helmet

Knee Boundary	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	10.199	in	10.199	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.611	in	7.613	in	0.002	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.671	in	8.673	in	0.001	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.317	in	6.317	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg

Torso Boundary

A torso boundry is not provided when the ACU ensemble is chosen

Elbow Boundary	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	29.627	in	29.627	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.479	in	11.479	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.304	in	21.304	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.303	in	7.305	in	0.002	in
ELBOW_Y_AXIS_LENGTH	3.424	in	3.425	in	0.001	in
ELBOW_Z_AXIS_LENGTH	5.665	in	5.668	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.004 inches
0.004 degrees

Values in agreement

206

Test #6: Surrogate Steering Wheel

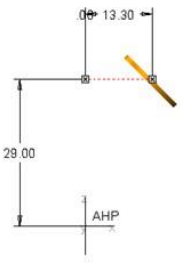
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

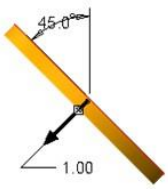
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

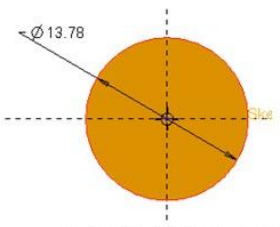
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

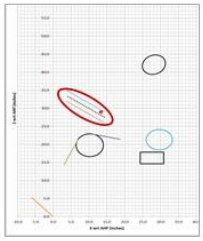
Side View **Steering Wheel Geometry**

207

Test #6: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

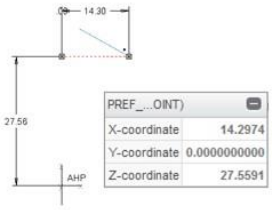
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



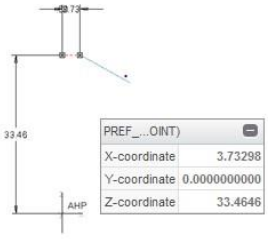
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



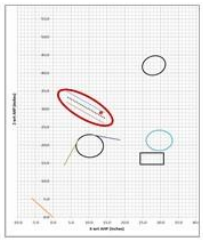
Preference Line Endpoint, Max

208

Test #6: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

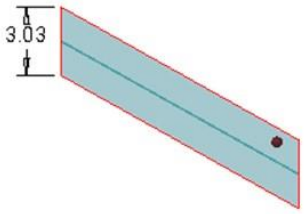
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.074	←
Upper Front	3.733	34.980	
Lower Rear	14.297	26.044	←
Lower Front	3.733	31.949	



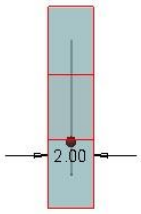
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

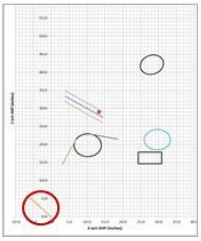
*Given value, not calculated

209

Test #6: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

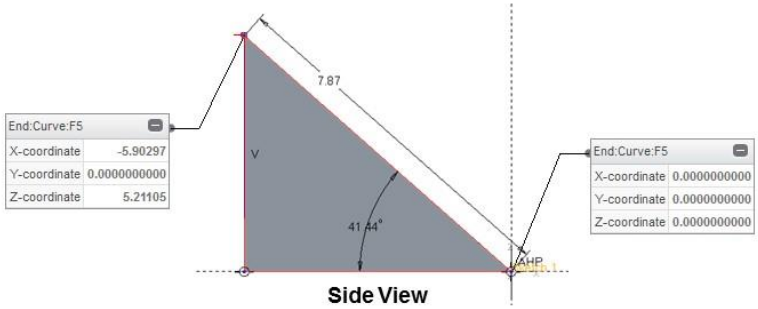
Accelerator Plane Angle (APA)	41.438 deg	
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

TARDEC CAD Model Geometry



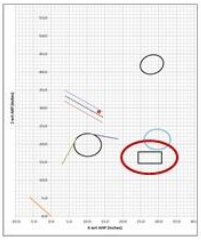
Side View

210

Test #6: Seat Track Travel Range

UMTRI Spreadsheet Calculations

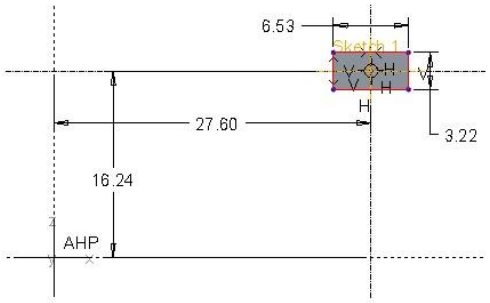
Center of Travel (X)	27.602	in
Center of Travel (Z)	16.244	in
Fore-Aft Travel (X)	6.535	in
Vertical Travel (Z)	3.223	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	27.603	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.244	in
SEAT_POSITION_FORE_AFT_TRAVEL	6.535	in
SEAT_POSITION_VERTICAL_TRAVEL	3.223	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 90.0 %
Ensemble: ACU (Advanced Combat Uniform)

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.6 in., Z = 16.2 in.)

211

Test #6: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	16.510 deg
Rear of Range	26.708 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.507	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.712	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 6.5 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.6 in., Z = 16.2 in.)

Seat Back Angle (wrt vertical): 16.5^{0} to 26.7^{0}

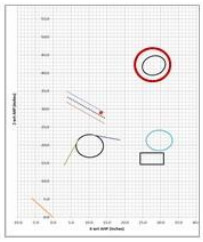
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

212

Test #6: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	28.114	1.280*	42.090
Left	28.114	-1.280*	42.090



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.570	in
Axis Length (Z')	→	5.236	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.387	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		28.114	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		42.090	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.573	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.240	in

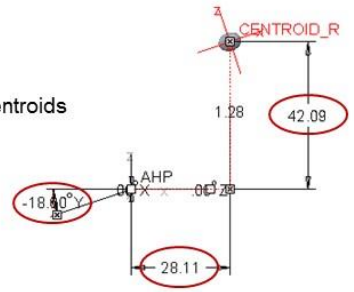
*Given value, not calculated

213

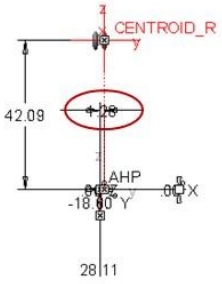
Test #6: Eyellipse (cont.)

TARDEC CAD Model Geometry

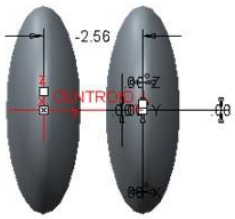
Centroids



Side View

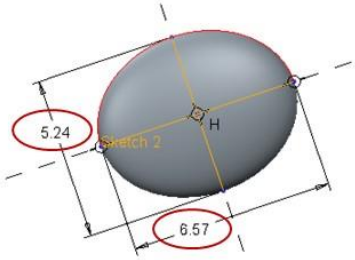


Rear View

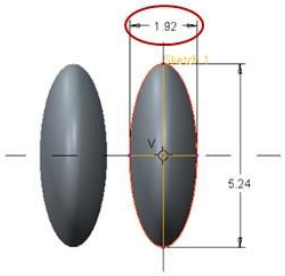


Rear View

Axis Lengths



Side View

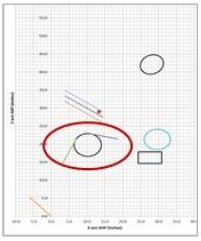


Rear View (Rotated)

Test #6: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	10.199	7.331	19.772
Left	10.199	-7.331	19.772



Side View of Knee Contours (X, Z)		
Axis Length (X)	7.611	in
Axis Length (Z)	6.317	in
Rear View of Knee Contours (Y, Z)		
Axis Length (Y)	8.671	in
Axis Length (Z)	6.317	in
Leg Segment Angle wrt Vertical	29.013	deg
Thigh Segment Angle wrt Horizontal	10.322	deg

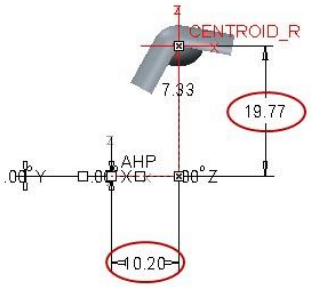
TARDEC CAD Model Calculations

KNEE_CONTOUR_WEIGHTED_CENT_X	10.199	in
KNEE_CONTOUR_WEIGHTED_CENT_Y	7.331	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.613	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.673	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.317	in
KNEE_SHIN_ANGLE	29.013	deg
KNEE_THIGH_ANGLE	10.322	deg

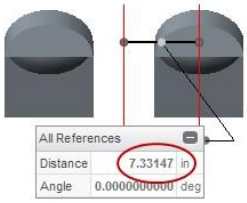
Test #6: Knee Boundary (cont.)

TARDEC CAD Model Result

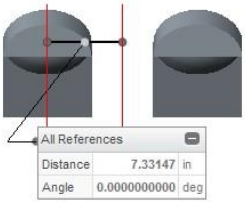
Centroids



Side View

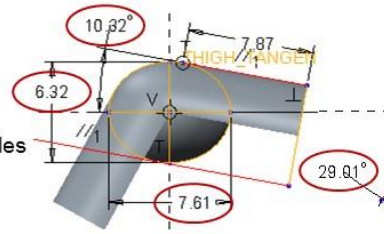


Rear View

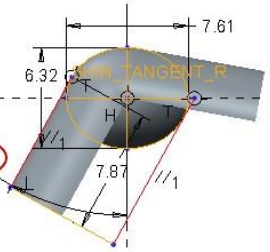


Rear View

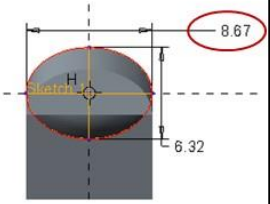
Axis Lengths
Shin/Thigh Angles



Side View



Side View



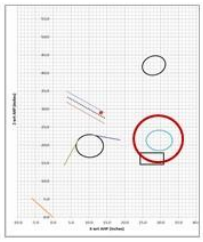
Rear View

216

Test #6: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	29.627	11.479	21.304
Left	29.627	-11.479	21.304



Side View of Elbow Contours (X, Z)

Axis Length (X)	→	7.303 in
Axis Length (Z)	→	5.665 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	→	3.424 in
Axis Length (Z)	→	5.665 in

TARDEC CAD Model Calculations

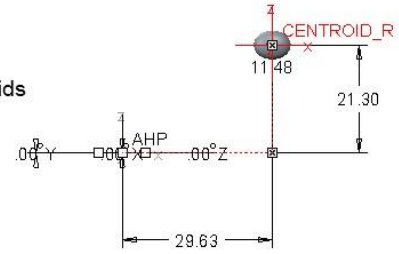
ELBOW_WEIGHTED_CENT_X		29.627	in
ELBOW_WEIGHTED_CENT_Y		11.479	in
ELBOW_WEIGHTED_CENT_Z		21.304	in
ELBOW_X_AXIS_LENGTH	→	7.305	in
ELBOW_Y_AXIS_LENGTH	→	3.425	in
ELBOW_Z_AXIS_LENGTH	→	5.668	in

217

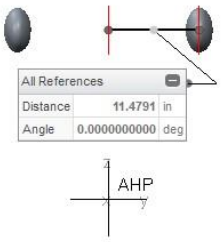
Test #6: Elbow Boundary (cont.)

TARDEC CAD Model Result

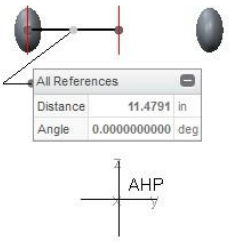
Centroids



Side View

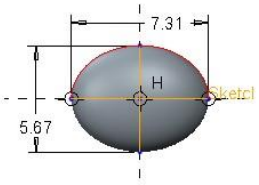


Rear View

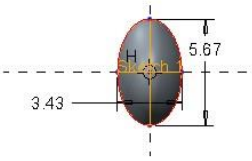


Rear View

Axis Lengths



Side View



Rear View

218

Test #6: Vary SWP and Ensemble

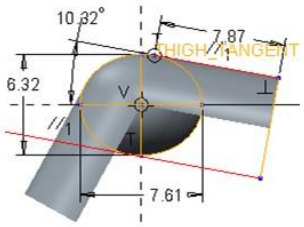
Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	ACU	13.3	29.0	No	SAE J826

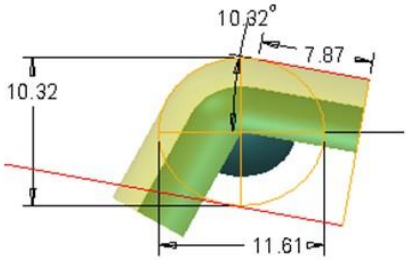
Clearance (2.0 inches), Shown in Yellow

TARDEC CAD Model

219

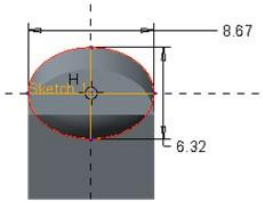
Test #6: Clearance, Knee Boundary

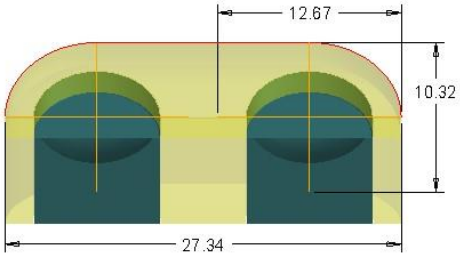




Sample Calculation: $\frac{1}{2}(10.317\ in. - 6.317\ in.) = 2.000\ in. clearance$

Side View





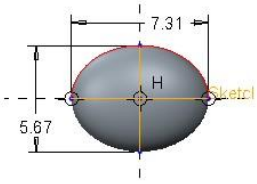
Rear View

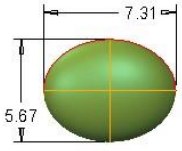
220

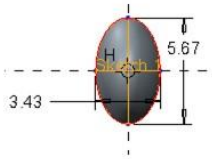
Test #6: Clearance, Elbow Boundary

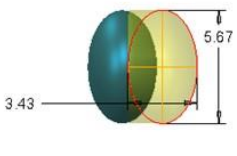
Sample Calculation: $13.479\ in. - 11.479\ in. = 2.000\ in. clearance$

Rear View









Side View **Rear View**

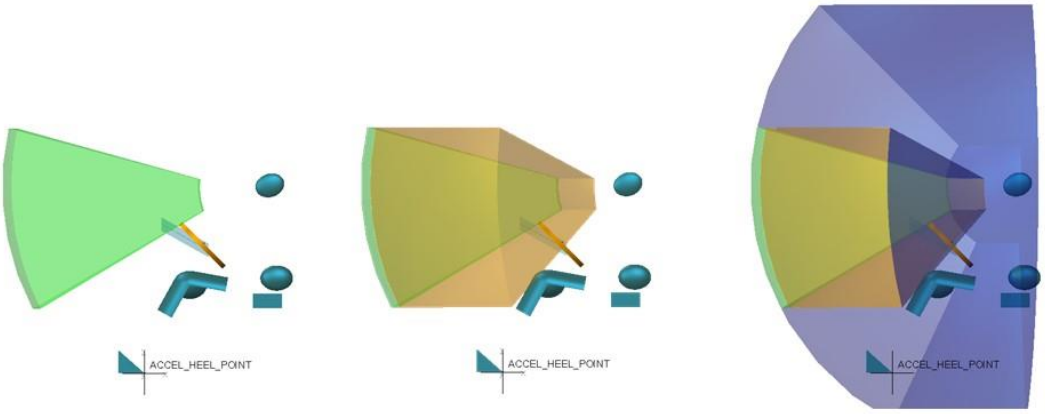
221

Test #6: Vary SWP and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	ACU	13.3	29.0	No	SAE J826

Vision Zones

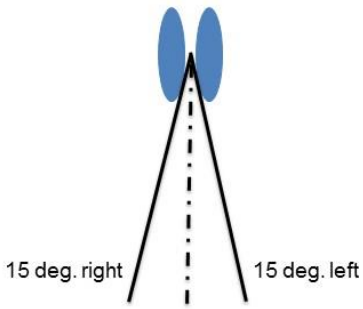
Vison zones are constructed geometrically; no calculations are involved.



Primary Zone | Secondary Zone | Tertiary Zone

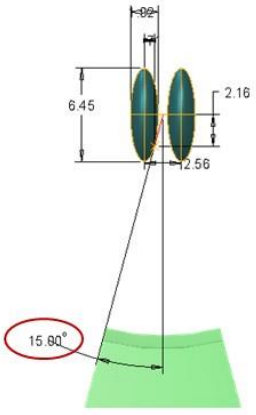
222

Test #6: Primary Vision Zone



Intent

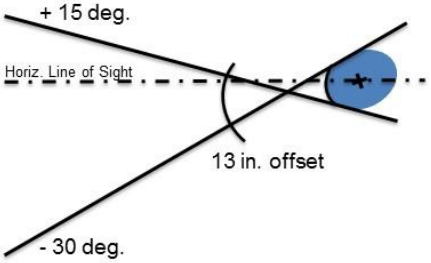
Top View



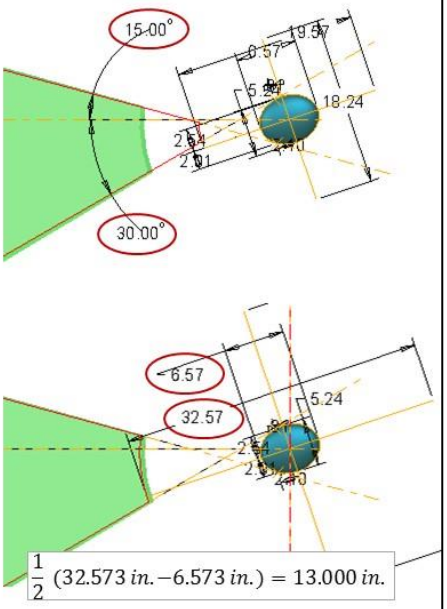
CAD Implementation

223

Test #6: Primary Vision Zone (cont.)



Side View

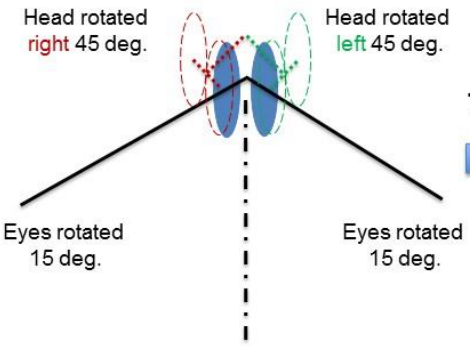


$$\frac{1}{2}\,(32.573\ in. - 6.573\ in.) = 13.000\ in.$$

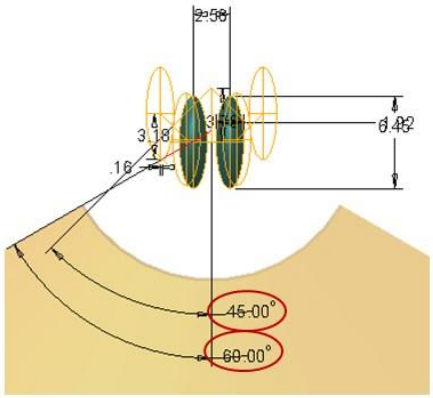
Intent | CAD Implementation

224

Test #6: Secondary Vision Zone



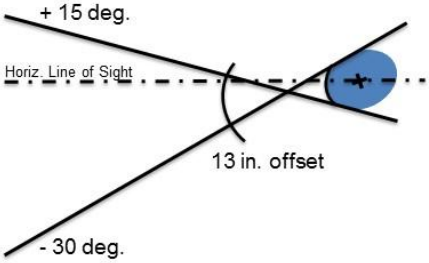
Top View



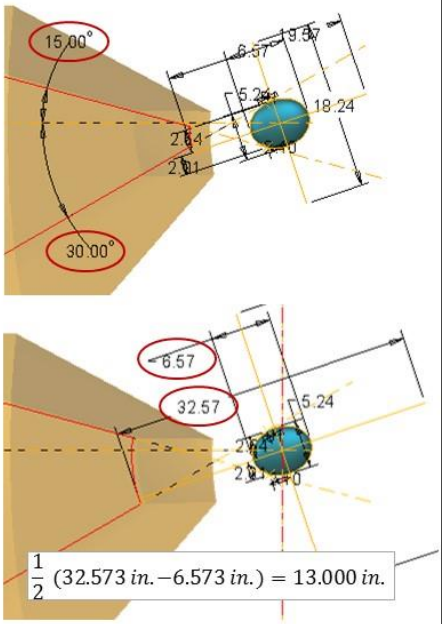
Intent | CAD Implementation

225

Test #6: Secondary Vision Zone (cont.)



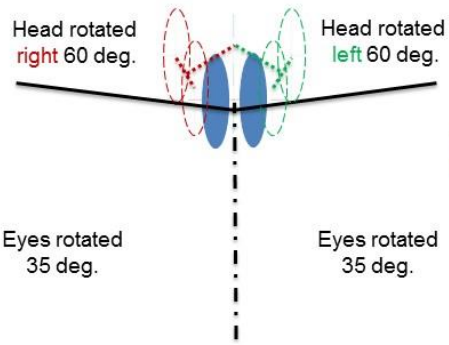
Side View



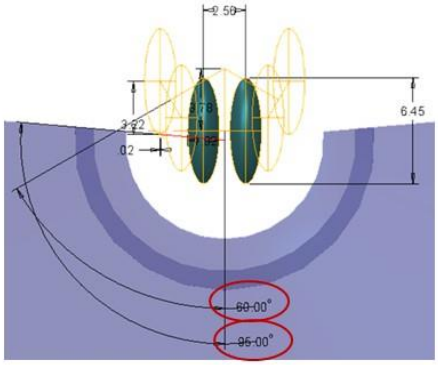
Intent | CAD Implementation

226

Test #6: Tertiary Vision Zone



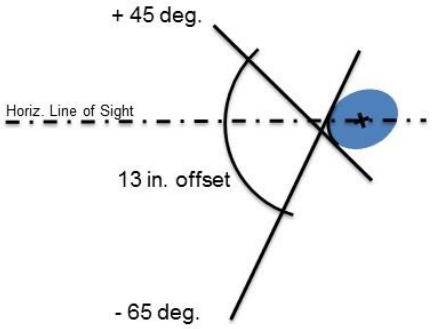
Top View



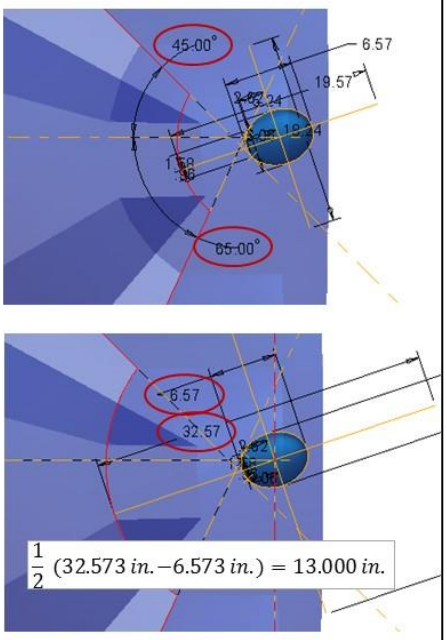
Intent | CAD Implementation

227

Test #6: Tertiary Vision Zone (cont.)



Side View



Intent | CAD Implementation

228

Test #6: Vary SWP and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	90%	ACU	13.3	29.0	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

229

Test #6: Numerical Results, Manikin Positioning

	UMTRI Value		TARDEC Value		Difference	
Small Overall Female						
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	26.357	in	26.357	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	27.608	in	27.608	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	29.017	in	29.017	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	29.673	in	29.673	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	29.183	in	29.183	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	30.593	in	30.593	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	30.370	in	30.370	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

230

Test #6: Small Overall Female

UMTRI Spreadsheet Calculations*

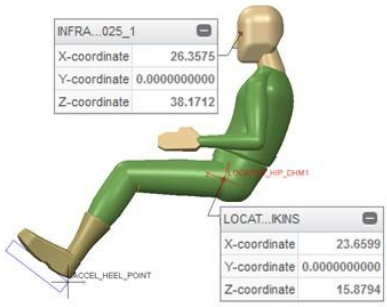
	ACU	PPE	ENC			
Hip re AHP X	601.0	601.0	618.6	→	23.660	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	26.357	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.660	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	26.357	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

231

Test #6: Small Overall Male

UMTRI Spreadsheet Calculations*

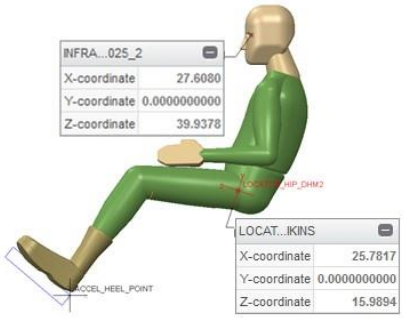
	ACU	PPE	ENC			
Hip re AHP X	654.9	654.9	672.5	→	25.782	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	27.608	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.782	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	27.608	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

232

Test #6: Average Size Male

UMTRI Spreadsheet Calculations*

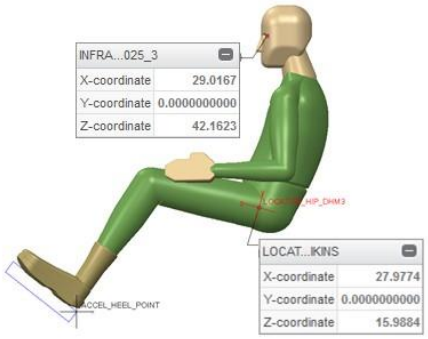
	ACU	PPE	ENC			
Hip re AHP X	710.6	710.6	728.2	→	27.977	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	29.017	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	27.977	in
POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_EYE_X	29.017	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

233

Test #6: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

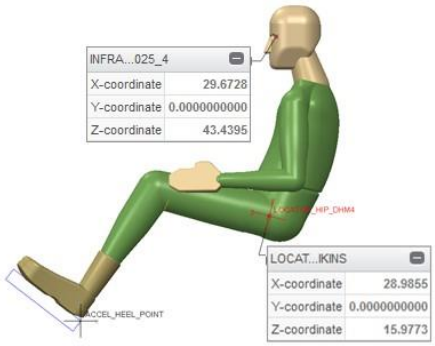
	ACU	PPE	ENC			
Hip re AHP X	736.2	736.2	753.8	→	28.985	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	29.673	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.986	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	29.673	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

234

Test #6: Longest Torso Male

UMTRI Spreadsheet Calculations*

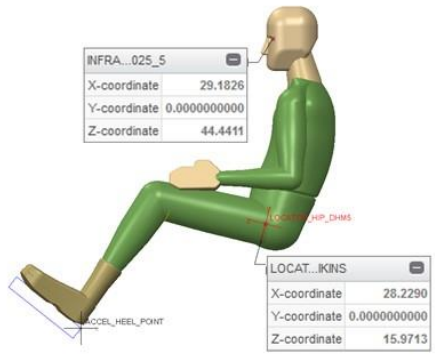
	ACU	PPE	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.229	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	29.183	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.229	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	29.183	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry



Side View

Front View

235

Test #6: Longest Legs Male

UMTRI Spreadsheet Calculations*

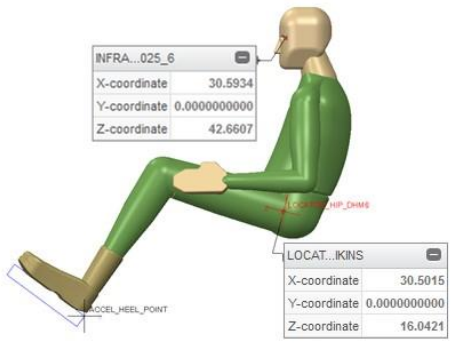
	ACU	PPE	ENC			
Hip re AHP X	774.7	774.7	792.3	→	30.501	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	30.593	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.502	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	30.593	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

236

Test #6: Large Overall Male

UMTRI Spreadsheet Calculations*

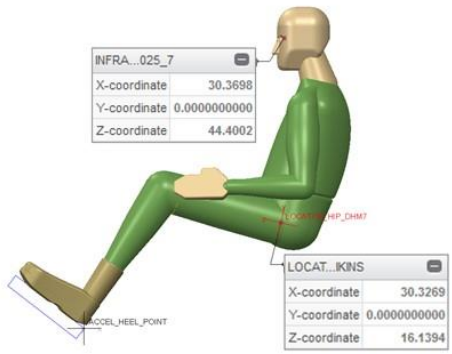
	ACU	PPE	ENC			
Hip re AHP X	770.3	770.3	787.9	→	30.327	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	30.370	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.327	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	30.370	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

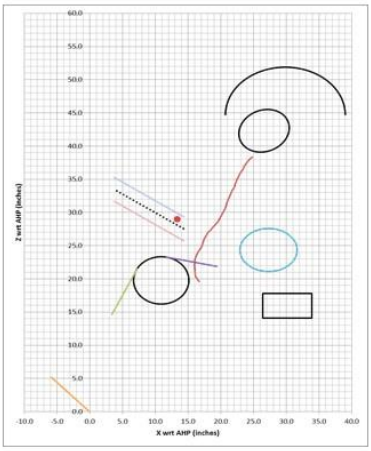
237

10.7.7 TEST #7 – VARY TARGET ACCOMMODATION AND ENSEMBLE

Test #7: Vary Target Accommodation and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
95%	90%	ENC	13.3	29.0	No	SAE J826

Basic Accommodation



TARDEC CAD Model

238

Test #7: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	14.297	in	14.297	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.733	in	3.733	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.806	in	1.806	in	0.000	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	30.119	in	30.121	in	0.002	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	15.949	in	15.949	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.515	in	7.506	in	0.008	in
SEAT_POSITION_VERTICAL_TRAVEL	3.698	in	3.695	in	0.004	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	18.133	deg	18.132	deg	0.001	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	30.285	deg	30.287	deg	0.001	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	26.593	in	26.594	in	0.001	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	42.304	in	42.304	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	7.832	in	7.833	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	2.284	in	2.285	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	6.243	in	6.244	in	0.001	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.837	in	29.838	in	0.001	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.721	in	44.721	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	18.284	in	18.285	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.882	in	9.883	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	14.328	in	14.329	in	0.001	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	10.896	in	10.896	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	7.331	in	7.331	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.772	in	19.772	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	8.436	in	8.435	in	0.000	in
KNEE_CONTOUR_Y_AXIS_LENGTH	9.529	in	9.527	in	0.002	in
KNEE_CONTOUR_Z_AXIS_LENGTH	7.134	in	7.130	in	0.004	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	10.322	deg	10.322	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_ENC_Z	16.513	in	16.517	in	0.004	in
TORSO_WEIGHTED_REF_PT_ENC_X	27.720	in	27.720	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	27.276	in	27.276	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	14.707	in	14.707	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.340	in	24.340	in	0.000	in
ELBOW_X_AXIS_LENGTH	8.744	in	8.742	in	0.002	in
ELBOW_Y_AXIS_LENGTH	4.102	in	4.101	in	0.001	in
ELBOW_Z_AXIS_LENGTH	6.486	in	6.488	in	0.001	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.008 inches
0.001 degrees

Values in agreement

239

Test #7: Surrogate Steering Wheel

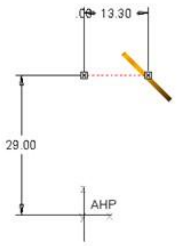
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

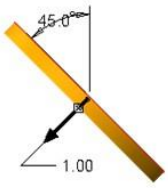
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

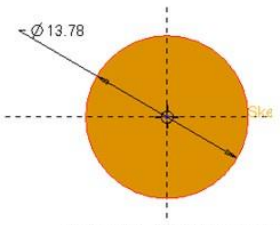
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

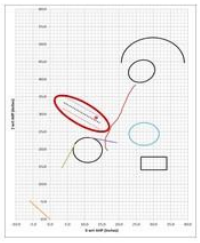
Side View **Steering Wheel Geometry**

240

Test #7: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

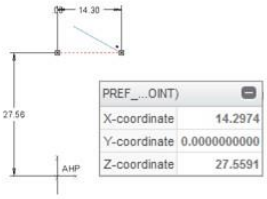
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	14.297	27.559
Preference Line Endpoint, Max	3.733	33.465



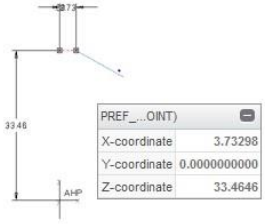
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	14.297	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.733	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



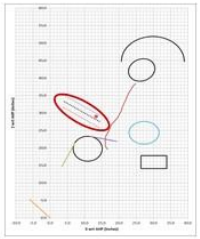
Preference Line Endpoint, Max

241

Test #7: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

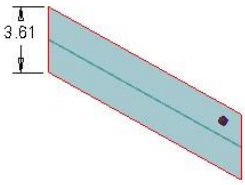
	L11 (in)	H17 (in)	
Upper Rear	14.297	29.365	←
Upper Front	3.733	35.270	
Lower Rear	14.297	25.753	←
Lower Front	3.733	31.659	



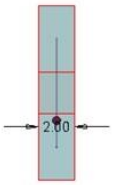
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.806	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.365\,in. - 25.753\,in. = 3.612\,in.$$

$$\frac{1}{2}(3.612\,in.) = 1.806\,in.$$

*Given value, not calculated

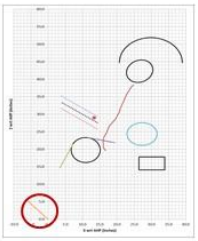
242

Test #7: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA) 41.438 deg

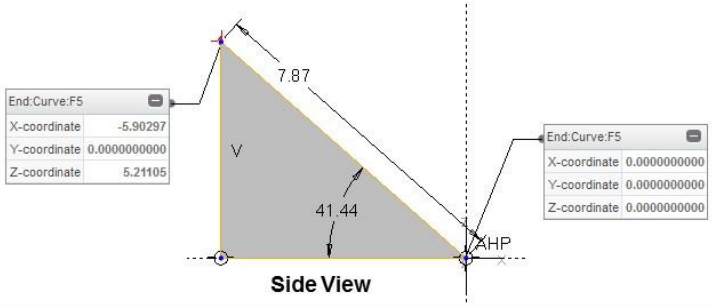
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

TARDEC CAD Model Geometry



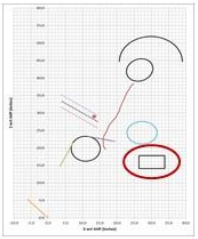
Side View

243

Test #7: Seat Track Travel Range

UMTRI Spreadsheet Calculations

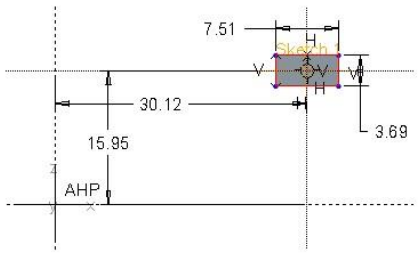
Center of Travel (X)	30.119	in
Center of Travel (Z)	15.949	in
Fore-Aft Travel (X)	7.515	in
Vertical Travel (Z)	3.698	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	30.121	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	15.949	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.506	in
SEAT_POSITION_VERTICAL_TRAVEL	3.695	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 95.0 %

Population Description
Fraction male: 90.0 %
Ensemble: ENC (PPE + Rifleman-like Gear)

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.5 in.
Vertical travel: 3.7 in.
Centered, via SAE J826, @ (X = 30.1 in., Z = 15.9 in.)

244

Test #7: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	18.133 deg
Rear of Range	30.285 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	18.132	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	30.287	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.5 in.
Vertical travel: 3.7 in.
Centered, via SAE J826, @ (X = 30.1 in., Z = 15.9 in.)

Seat Back Angle (wrt vertical): 18.1^{0} to 30.3^{0}

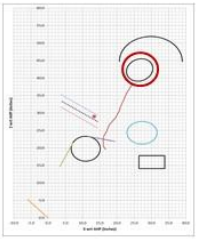
Warnings
-- Manikins with upper legs less than 5 deg above horiz:
#1 #2

245

Test #7: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	26.593	1.280*	42.304
Left	26.593	-1.280*	42.304



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	7.832	in
Axis Length (Z')	→	6.243	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	2.284	in
Axis Length (Z)		6.423	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		26.594	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		42.304	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	7.833	in
EYELLIPSE_Y_AXIS_LENGTH	→	2.285	in
EYELLIPSE_Z_AXIS_LENGTH	→	6.244	in

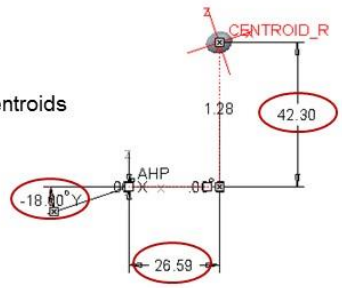
*Given value, not calculated

246

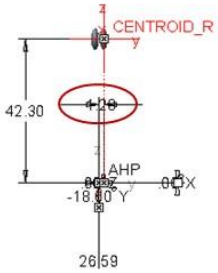
Test #7: Eyellipse (cont.)

TARDEC CAD Model Geometry

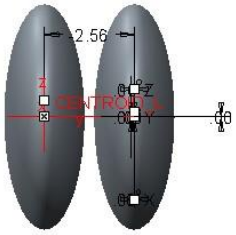
Centroids



Side View

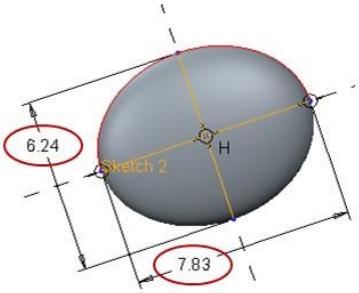


Rear View

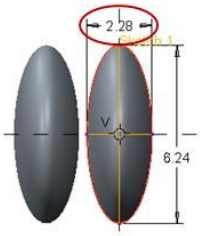


Rear View

Axis Lengths



Side View



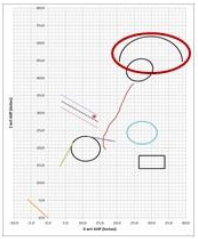
Rear View (Rotated)

247

Test #7: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	29.837	2.185*	44.721
Left	29.837	-2.185*	44.721



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	18.284	in
Axis Length (Z)	→	14.328	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.882	in
Axis Length (Z)	→	14.328	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		29.838	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		44.721	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	18.285	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.883	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	14.329	in

$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

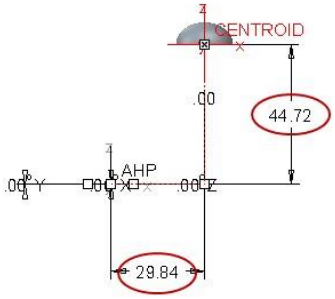
*Given value, not calculated

248

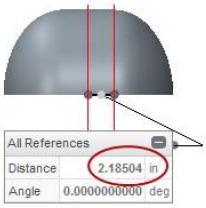
Test #7: Helmet Boundary (cont.)

TARDEC CAD Model Result

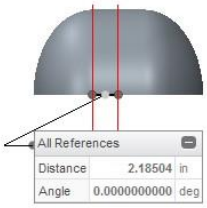
Centroids



Side View

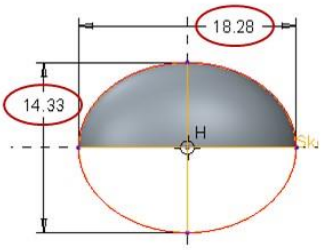


Rear View

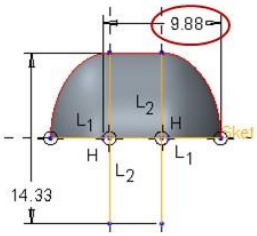


Rear View

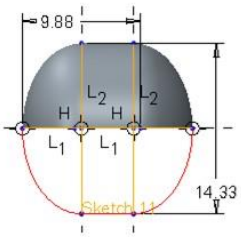
Axis Lengths



Side View



Rear View



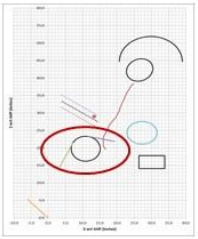
Rear View

249

Test #7: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	10.896	7.331	19.772
Left	10.896	-7.331	19.772



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	8.436	in
Axis Length (Z)	→	7.134	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	9.529	in
Axis Length (Z)	→	7.134	in
Leg Segment Angle wrt Vertical		29.013	deg
Thigh Segment Angle wrt Horizontal		10.322	deg

TARDEC CAD Model Calculations

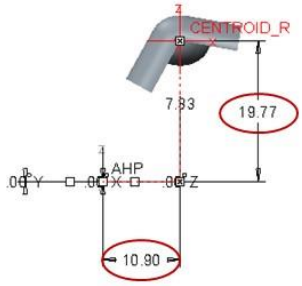
KNEE_CONTOUR_WEIGHTED_CENT_X		10.896	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		7.331	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		19.772	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	8.435	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	9.527	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	7.130	in
KNEE_SHIN_ANGLE		29.013	deg
KNEE_THIGH_ANGLE		10.322	deg

250

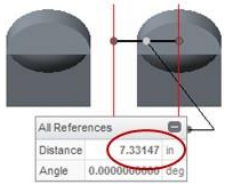
Test #7: Knee Boundary (cont.)

TARDEC CAD Model Result

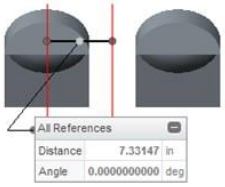
Centroids



Side View

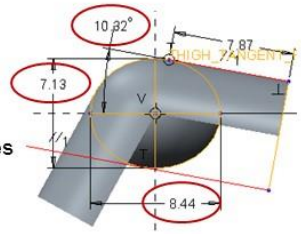


Rear View

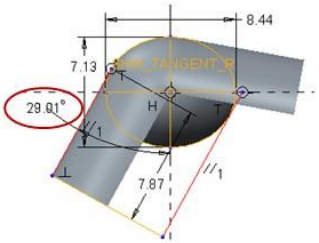


Rear View

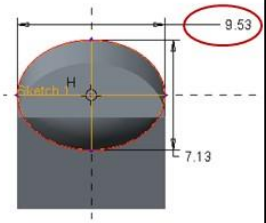
Axis Lengths
Shin/Thigh Angles



Side View



Side View

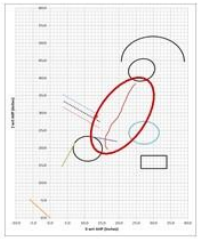


Rear View

Test #7: Torso Boundary (ENC)

UMTRI Spreadsheet Calculations

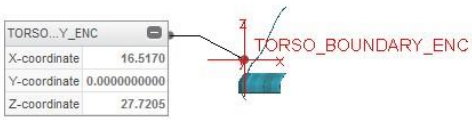
Mean Reference Point	X (in)	Z (in)
PPE	23.503	33.252
ENC	→ 16.513	27.720 ←



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_ENC_X	16.517	in
TORSO_WEIGHTED_REF_PT_ENC_Z	27.720	in

TARDEC CAD Model Geometry

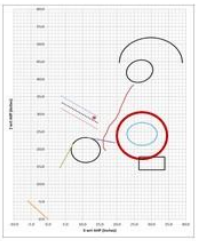


Side View

Test #7: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	27.276	14.707	24.340
Left	27.276	-14.707	24.340



Side View of Elbow Contours (X, Z)

Axis Length (X)	→	8.744 in
Axis Length (Z)	→	6.486 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	→	4.102 in
Axis Length (Z)	→	6.486 in

TARDEC CAD Model Calculations

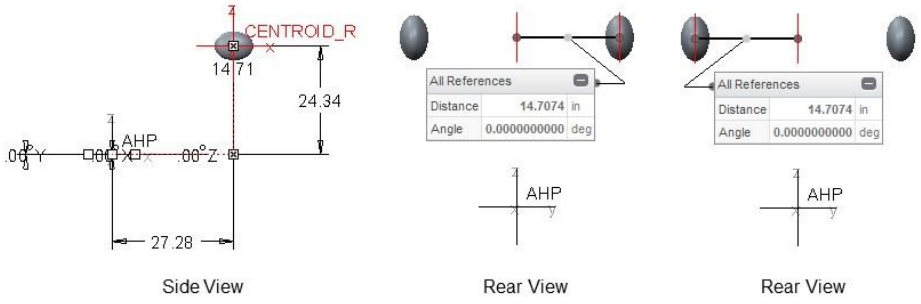
ELBOW_WEIGHTED_CENT_X		27.276	in
ELBOW_WEIGHTED_CENT_Y		14.707	in
ELBOW_WEIGHTED_CENT_Z		24.340	in
ELBOW_X_AXIS_LENGTH	→	8.742	in
ELBOW_Y_AXIS_LENGTH	→	4.101	in
ELBOW_Z_AXIS_LENGTH	→	6.488	in

253

Test #7: Elbow Boundary (cont.)

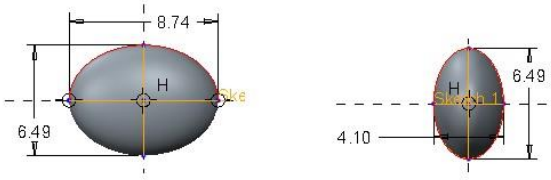
TARDEC CAD Model Result

Centroids



Side View | Rear View | Rear View

Axis Lengths



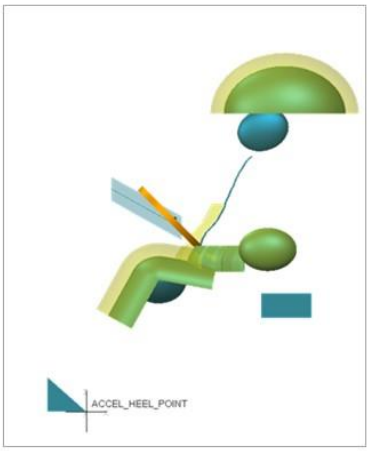
Side View | Rear View

254

Test #7: Vary Target Accommodation and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
95%	90%	ENC	13.3	29.0	No	SAE J826

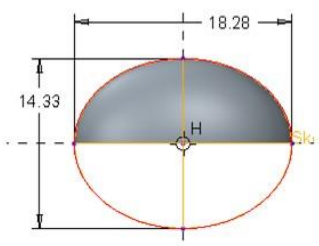
Clearance (2.0 inches), Shown in Yellow

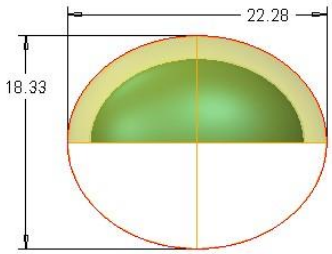


TARDEC CAD Model

255

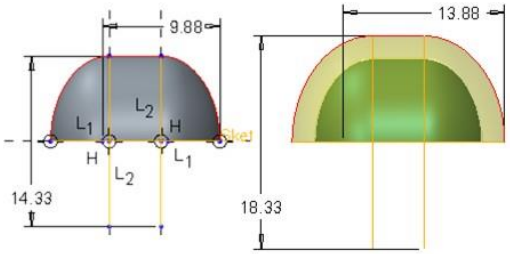
Test #7: Clearance, Helmet Boundary

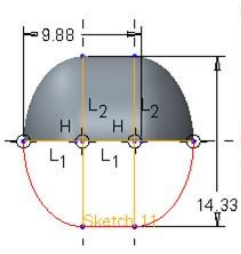


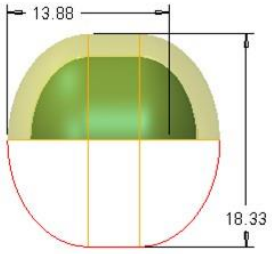


$$Sample\ Calculation: \frac{1}{2}\,(22.285\,in. - 18.285\,in.) = 2.000\,in.\,clearance$$

Side View



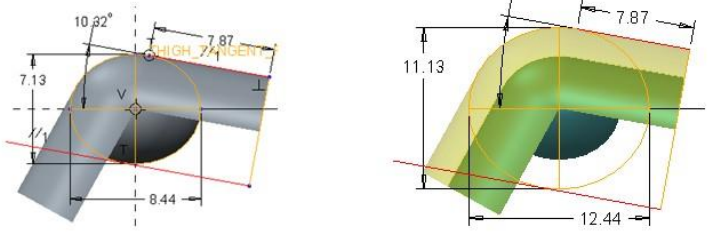




Rear View

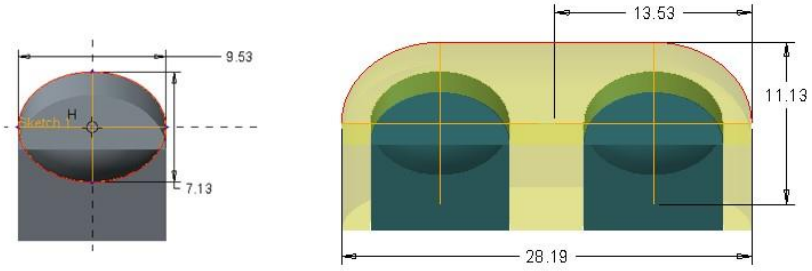
256

Test #7: Clearance, Knee Boundary



Sample Calculation: $\frac{1}{2}$ (11.130 *in.* − 7.130 *in.*) = 2.000 *in. clearance*

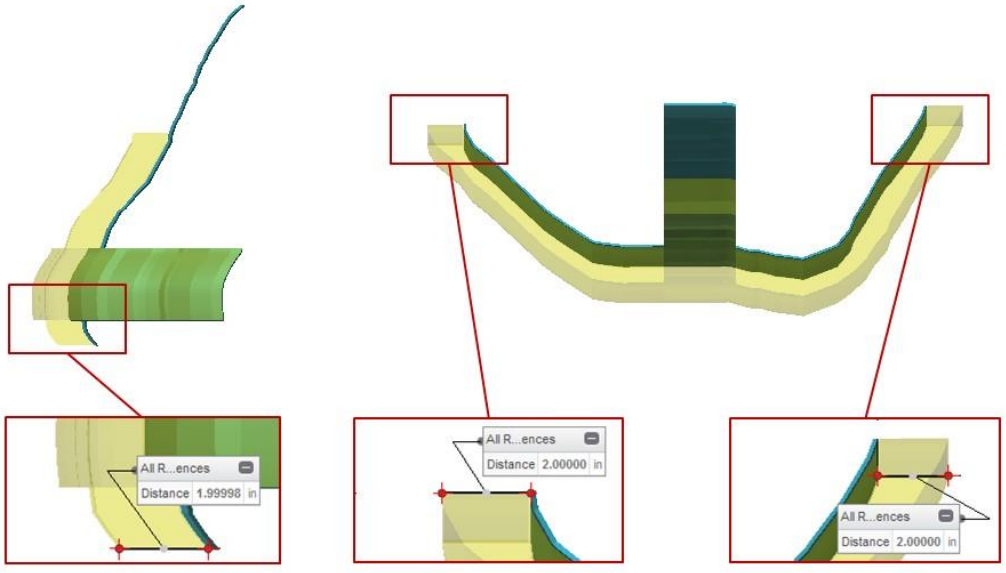
Side View



Rear View

257

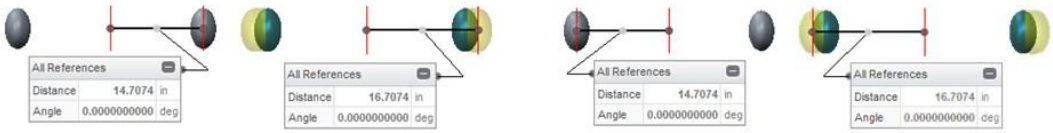
Test #7: Clearance, Torso Boundary (ENC)



Side View **Top View**

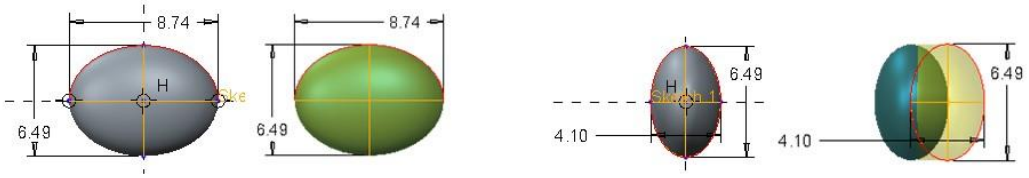
258

Test #7: Clearance, Elbow Boundary



Sample Calculation: 16.707 *in.* − 14.707 *in.* = 2.000 *in. clearance*

Rear View



Side View **Rear View**

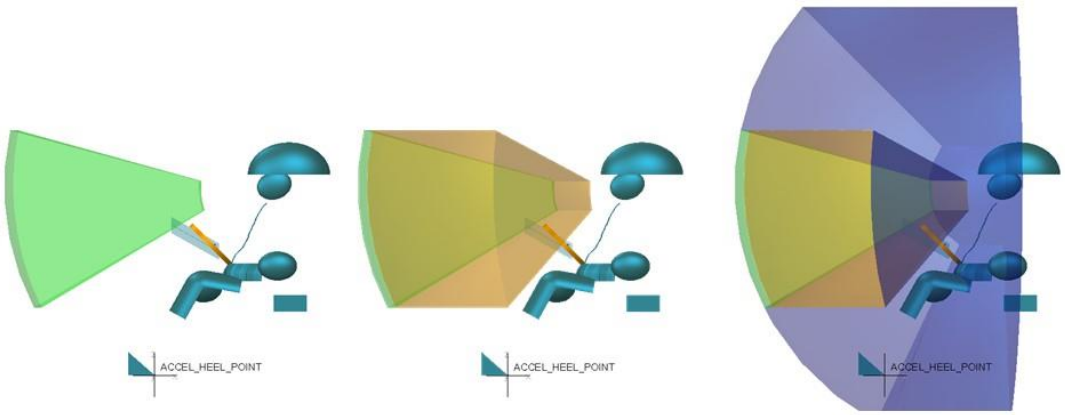
259

Test #7: Vary Target Accommodation and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
95%	90%	ENC	13.3	29.0	No	SAE J826

Vision Zones

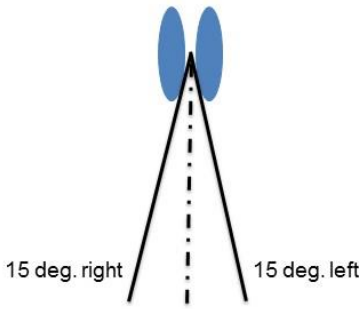
Vison zones are constructed geometrically; no calculations are involved.



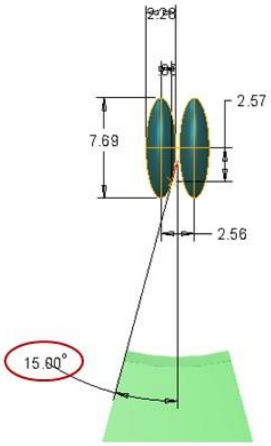
Primary Zone Secondary Zone Tertiary Zone

260

Test #7: Primary Vision Zone



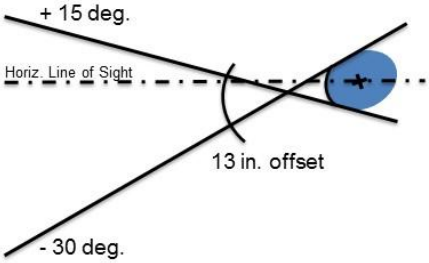
Top View



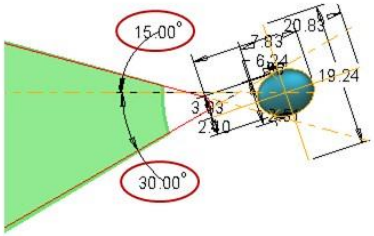
Intent **CAD Implementation**

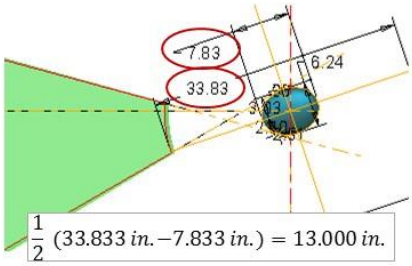
261

Test #7: Primary Vision Zone (cont.)



Side View

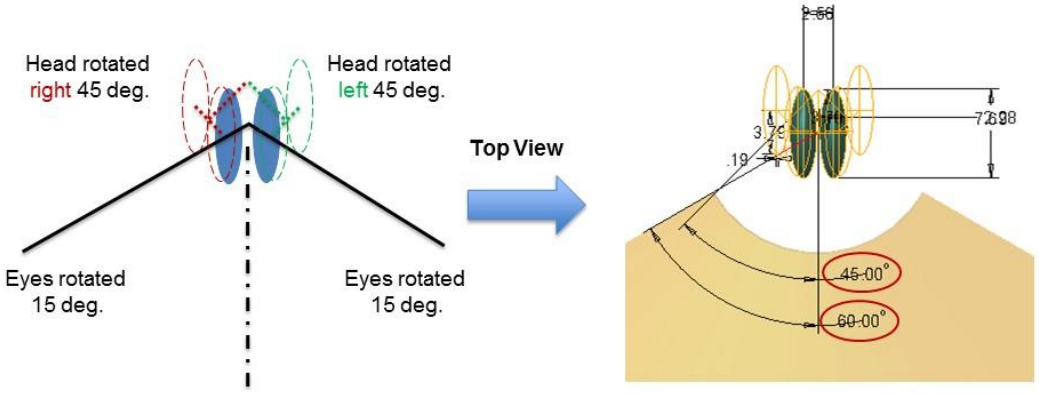




Intent **CAD Implementation**

262

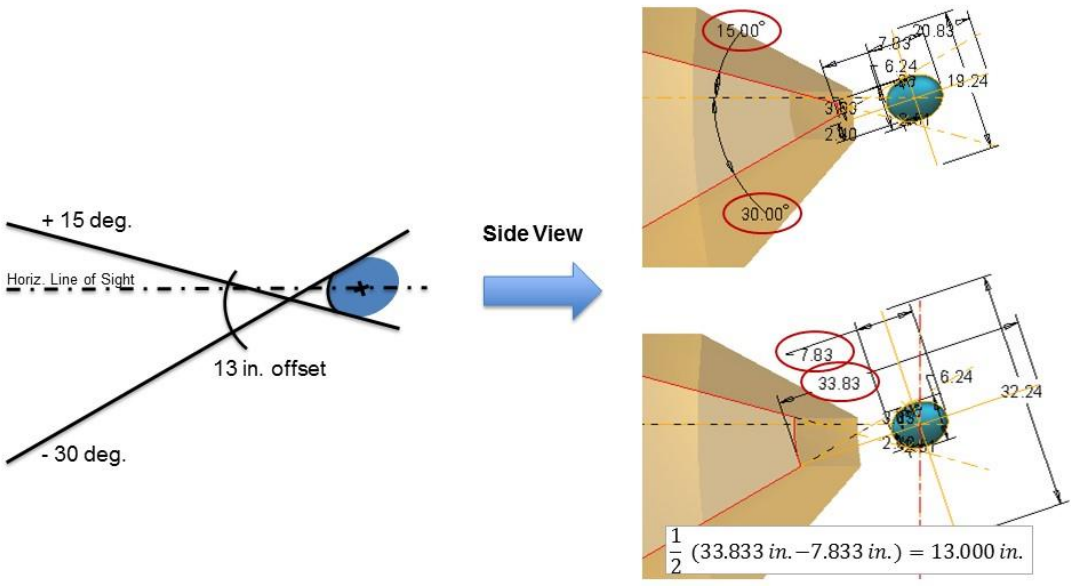
Test #7: Secondary Vision Zone



Intent CAD Implementation

263

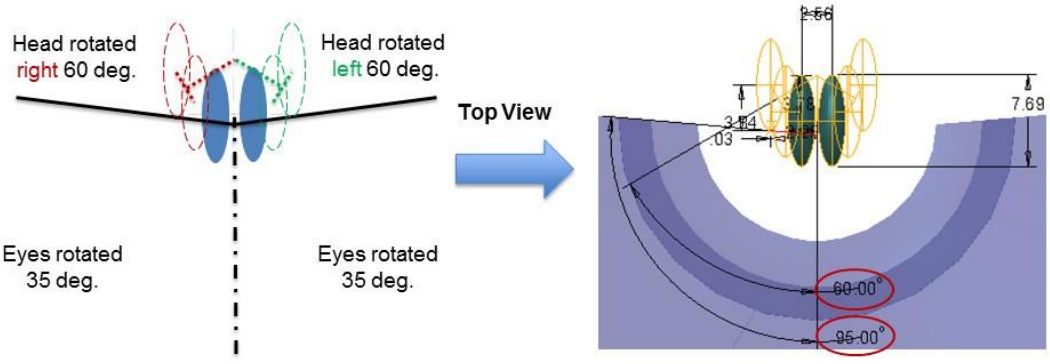
Test #7: Secondary Vision Zone (cont.)



Intent CAD Implementation

264

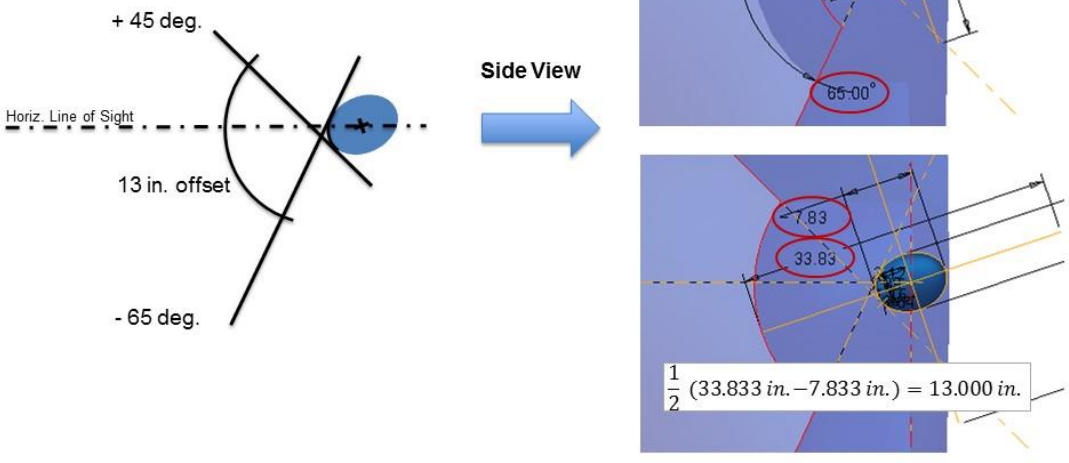
Test #7: Tertiary Vision Zone



Intent | CAD Implementation

265

Test #7: Tertiary Vision Zone (cont.)



Intent | CAD Implementation

266

Test #7: Vary Target Accommodation and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
95%	90%	ENC	13.3	29.0	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

267

Test #7: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	24.353	in	24.353	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.822	in	24.822	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	26.475	in	26.475	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.073	in	26.073	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	28.670	in	28.670	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.481	in	27.481	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	29.678	in	29.678	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.137	in	28.137	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.922	in	28.922	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.647	in	27.647	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	31.194	in	31.194	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.058	in	29.058	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	31.020	in	31.020	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.834	in	28.834	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

268

Test #7: Small Overall Female

UMTRI Spreadsheet Calculations*

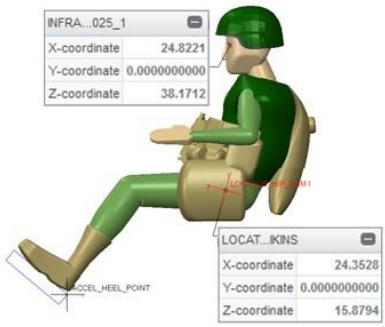
	ACU	PPE	ENC			
Hip re AHP X	601.0	601.0	618.6	→	24.353	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	24.822	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	24.353	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	24.822	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

269

Test #7: Small Overall Male

UMTRI Spreadsheet Calculations*

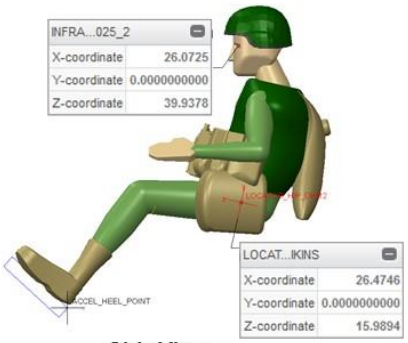
	ACU	PPE	ENC			
Hip re AHP X	654.9	654.9	672.5	→	26.475	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	26.073	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	26.475	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	26.073	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

270

Test #7: Average Size Male

UMTRI Spreadsheet Calculations*

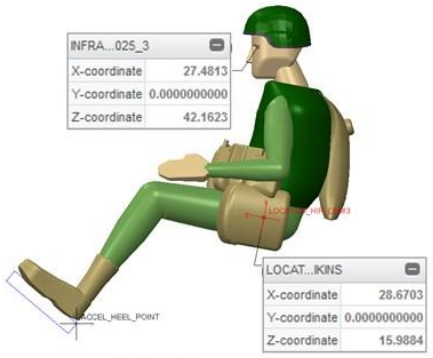
	ACU	PPE	ENC			
Hip re AHP X	710.6	710.6	728.2	→	28.670	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	27.481	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	28.670	in
POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_EYE_X	27.481	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

271

Test #7: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

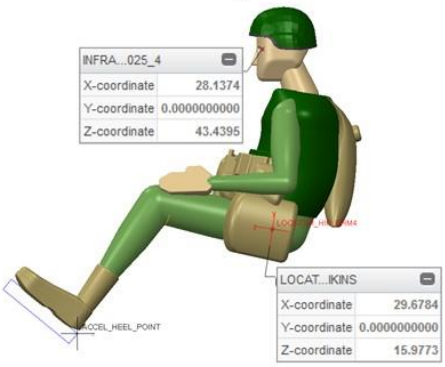
	ACU	PPE	ENC			
Hip re AHP X	736.2	736.2	753.8	→	29.678	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	28.137	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	29.678	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	28.137	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

272

Test #7: Longest Torso Male

UMTRI Spreadsheet Calculations*

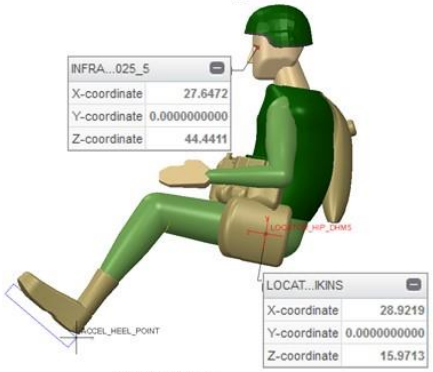
	ACU	PPE	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.922	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	27.647	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.922	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	27.647	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry



Side View

Front View

273

Test #7: Longest Legs Male

UMTRI Spreadsheet Calculations*

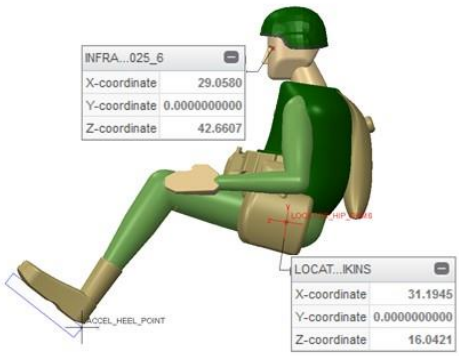
	ACU	PPE	ENC			
Hip re AHP X	774.7	774.7	792.3	→	31.194	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	29.058	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	31.194	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	29.058	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

274

Test #7: Large Overall Male

UMTRI Spreadsheet Calculations*

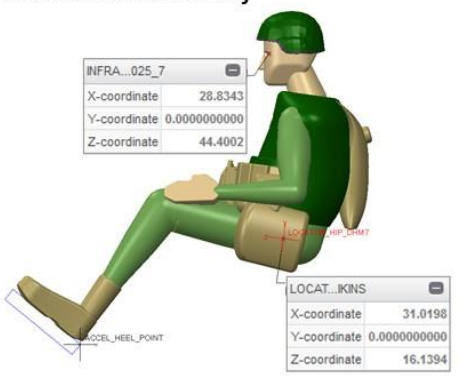
	ACU	PPE	ENC			
Hip re AHP X	770.3	770.3	787.9	→	31.020	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	28.834	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	31.020	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	28.834	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

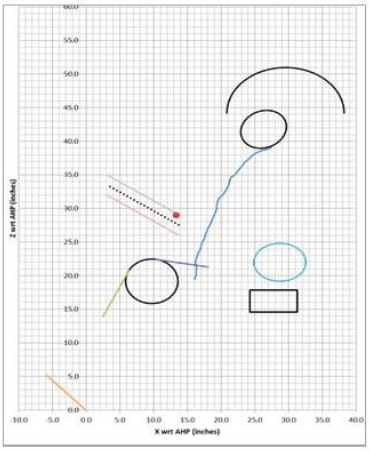
275

10.7.8 TEST #8 – VARY GENDER MIX AND ENSEMBLE

Test #8: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	PPE	13.3	29.0	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

276

Test #8: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in	27.766	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.220	in	16.220	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.045	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	26.271	in	26.271	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.779	in	41.779	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.515	in	29.515	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	44.196	in	44.196	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.358	in	17.359	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.548	in	13.550	in	0.002	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	9.709	in	9.709	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_PPE_X	21.517	in	21.517	in	0.000	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.076	in	33.076	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	28.690	in	28.690	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.922	in	11.922	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.981	in	21.981	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

277

Test #8: Surrogate Steering Wheel

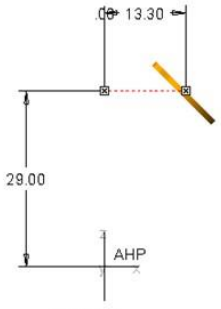
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

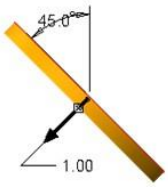
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

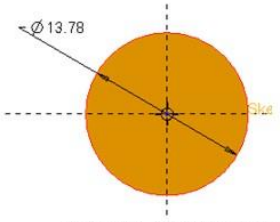
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

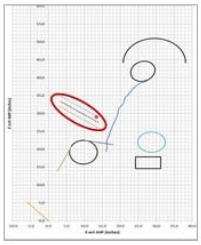
Side View **Steering Wheel Geometry**

278

Test #8: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

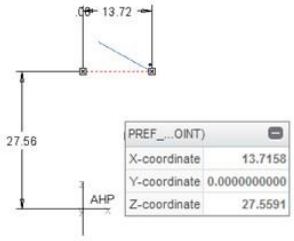
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	13.716	27.559
Preference Line Endpoint, Max	3.151	33.465



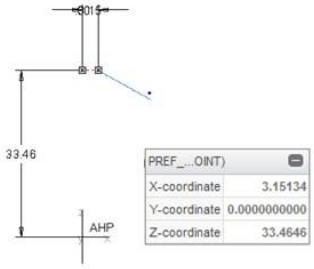
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	13.716	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.151	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



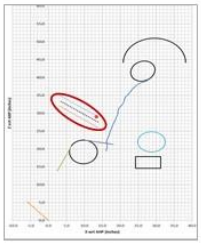
Preference Line Endpoint, Max

279

Test #8: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

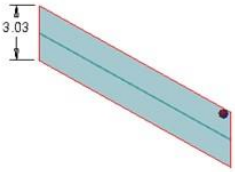
	L11 (in)	H17 (in)	
Upper Rear	13.716	29.074	←
Upper Front	3.151	34.980	
Lower Rear	13.716	26.044	←
Lower Front	3.151	31.949	



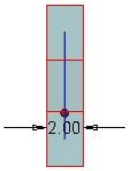
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

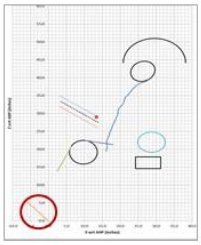
$29.074\ in. - 26.044\ in. = 3.030\ in.$

$\frac{1}{2}(3.030\ in.) = 1.515\ in.$

*Given value, not calculated

280

Test #8: Accelerator Plane Angle (APA)



UMTRI Spreadsheet Calculations

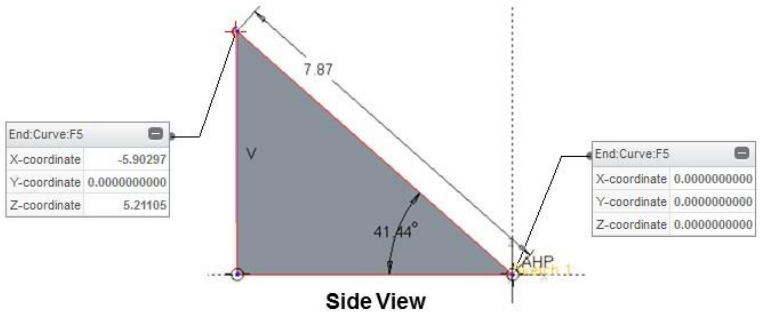
Accelerator Plane Angle (APA) 41.438 deg

	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211

TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

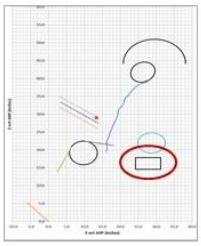
TARDEC CAD Model Geometry



Side View

281

Test #8: Seat Track Travel Range



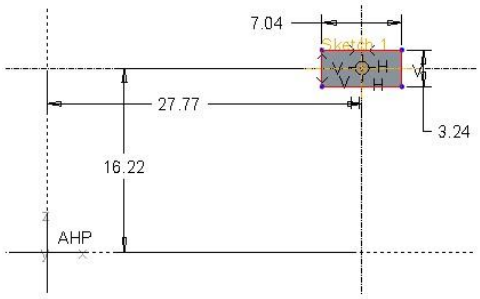
UMTRI Spreadsheet Calculations

Center of Travel (X)	27.766	in
Center of Travel (Z)	16.220	in
Fore-Aft Travel (X)	7.045	in
Vertical Travel (Z)	3.234	in

TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.220	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in
SEAT_POSITION_VERTICAL_TRAVEL	3.235	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 50.0 %
Ensemble: PPE (ACU + IOTV + Helmet (ACH))

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.0 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.8 in., Z = 16.2 in.)

282

Test #8: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	16.510 deg
Rear of Range	26.708 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.507	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.712	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.0 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.8 in., Z = 16.2 in.)

Seat Back Angle (wrt vertical): 16.5^{o} to 26.7^{o}

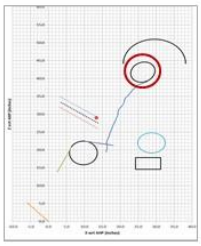
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

283

Test #8: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	26.271	1.280*	41.779
Left	26.271	-1.280*	41.779



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.889	in
Axis Length (Z')	→	5.484	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.643	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		26.271	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		41.779	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.890	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.486	in

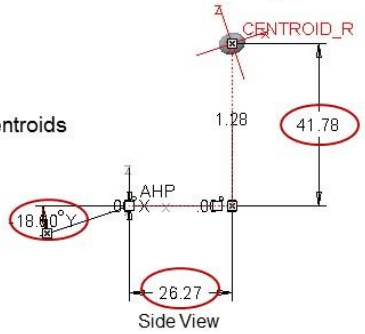
*Given value, not calculated

284

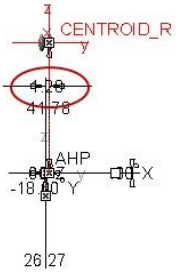
Test #8: Eyellipse (cont.)

TARDEC CAD Model Geometry

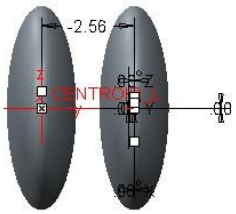
Centroids



Side View

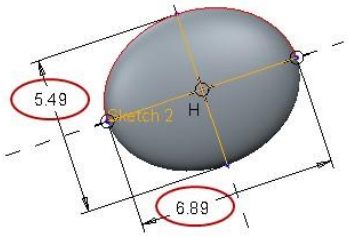


Rear View

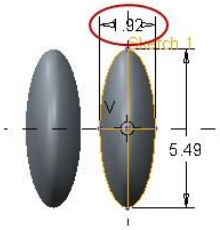


Rear View

Axis Lengths



Side View



Rear View (Rotated)

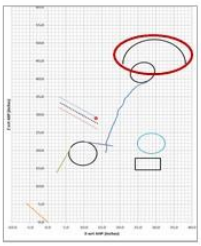
285

Test #8: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	29.515	2.185*	44.196
Left	29.515	-2.185*	44.196

Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.358	in
Axis Length (Z)	→	13.548	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)		13.548	in



TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		29.515	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		44.196	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.359	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.550	in

$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

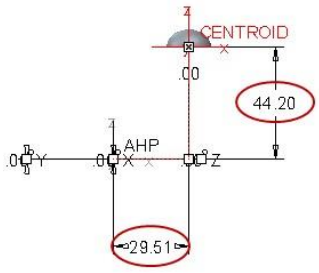
*Given value, not calculated

286

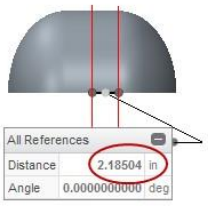
Test #8: Helmet Boundary (cont.)

TARDEC CAD Model Result

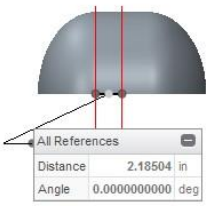
Centroids



Side View

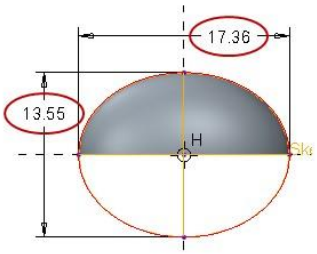


Rear View

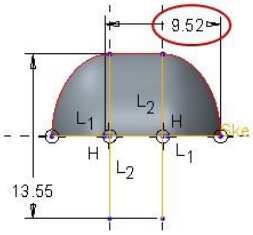


Rear View

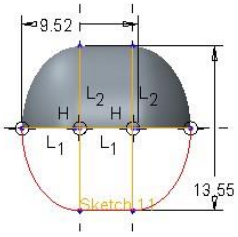
Axis Lengths



Side View



Rear View



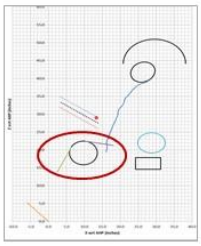
Rear View

287

Test #8: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	9.709	6.817	19.163
Left	9.709	-6.817	19.163



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.753	in
Axis Length (Z)	→	6.615	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.895	in
Axis Length (Z)	→	6.615	in
Leg Segment Angle wrt Vertical		29.013	deg
Thigh Segment Angle wrt Horizontal		8.489	deg

TARDEC CAD Model Calculations

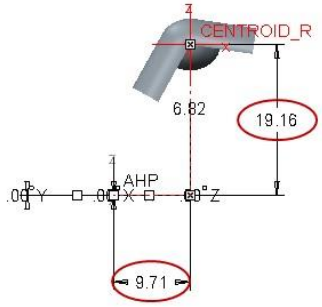
KNEE_CONTOUR_WEIGHTED_CENT_X		9.709	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		6.817	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		19.163	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.754	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.896	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	6.615	in
KNEE_SHIN_ANGLE		29.013	deg
KNEE_THIGH_ANGLE		8.489	deg

288

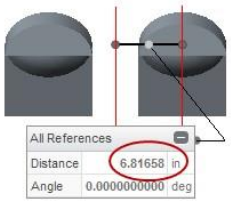
Test #8: Knee Boundary (cont.)

TARDEC CAD Model Result

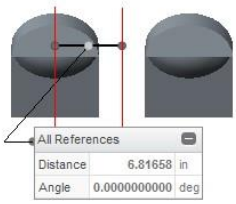
Centroids



Side View

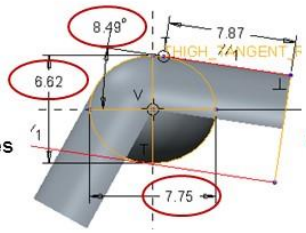


Rear View

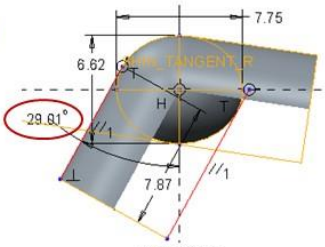


Rear View

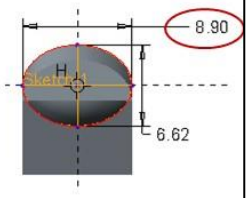
Axis Lengths
Shin/Thigh Angles



Side View



Side View



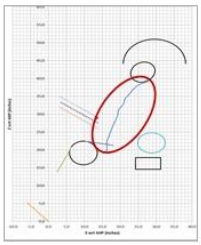
Rear View

289

Test #8: Torso Boundary (PPE)

UMTRI Spreadsheet Calculations

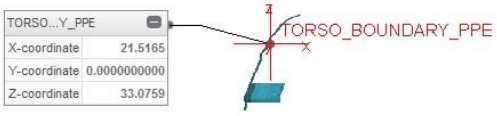
Mean Reference Point	X (in)	Z (in)
PPE	21.517	33.076
ENC	14.255	27.992



TARDEC CAD Model Calculations

TORSO_WEIGHTED_REF_PT_PPE_X	21.517	in
TORSO_WEIGHTED_REF_PT_PPE_Z	33.076	in

TARDEC CAD Model Geometry



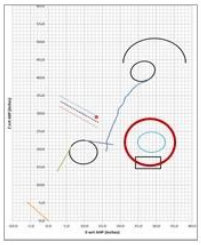
Side View

290

Test #8: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	28.690	11.922	21.981
Left	28.690	-11.922	21.981



Side View of Elbow Contours (X, Z)

Axis Length (X)	7.680 in
Axis Length (Z)	5.652 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	3.599 in
Axis Length (Z)	5.652 in

TARDEC CAD Model Calculations

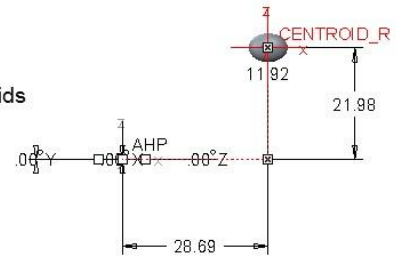
ELBOW_WEIGHTED_CENT_X	28.690	in
ELBOW_WEIGHTED_CENT_Y	11.922	in
ELBOW_WEIGHTED_CENT_Z	21.981	in
ELBOW_X_AXIS_LENGTH	7.681	in
ELBOW_Y_AXIS_LENGTH	3.599	in
ELBOW_Z_AXIS_LENGTH	5.655	in

291

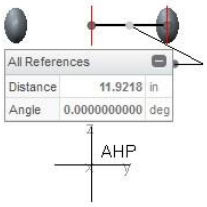
Test #8: Elbow Boundary (cont.)

TARDEC CAD Model Result

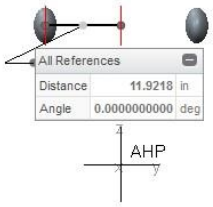
Centroids



Side View

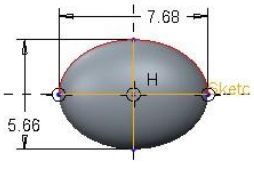


Rear View

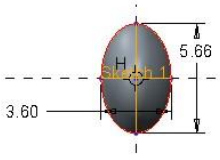


Rear View

Axis Lengths



Side View



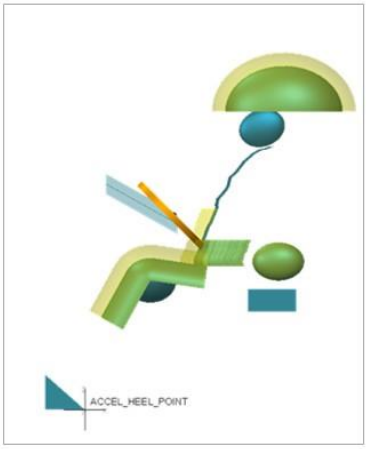
Rear View

292

Test #8: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	PPE	13.3	29.0	No	SAE J826

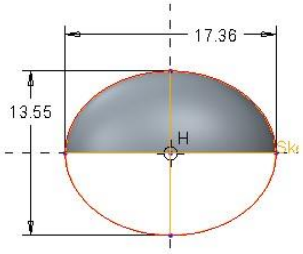
Clearance (2.0 inches), Shown in Yellow

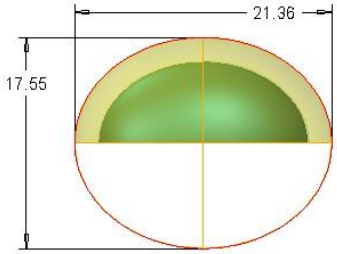


TARDEC CAD Model

293

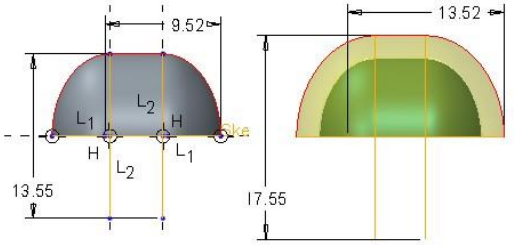
Test #8: Clearance, Helmet Boundary

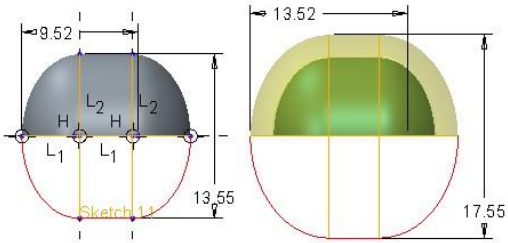




$$Sample\ Calculation: \frac{1}{2}\ (21.359\ in. - 17.359\ in.) = 2.000\ in. clearance$$

Side View

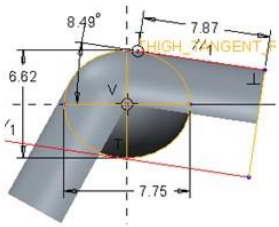


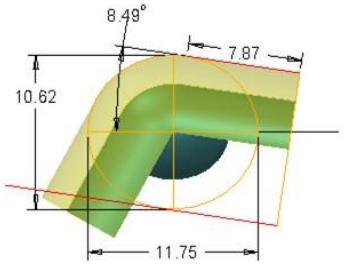


Rear View

294

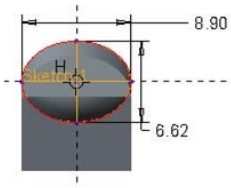
Test #8: Clearance, Knee Boundary

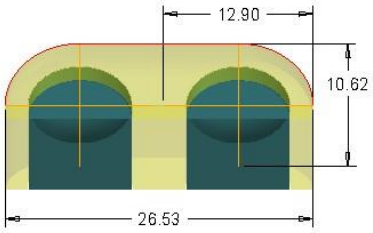




Sample Calculation: $\frac{1}{2}(10.615\,in. - 6.615\,in.) = 2.000\,in.\,clearance$

Side View

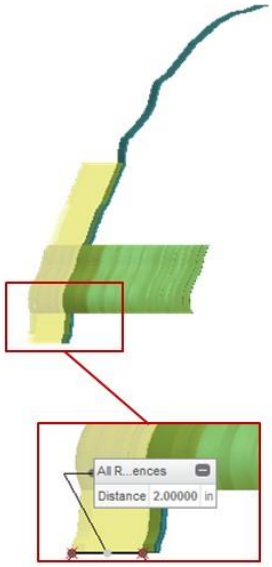


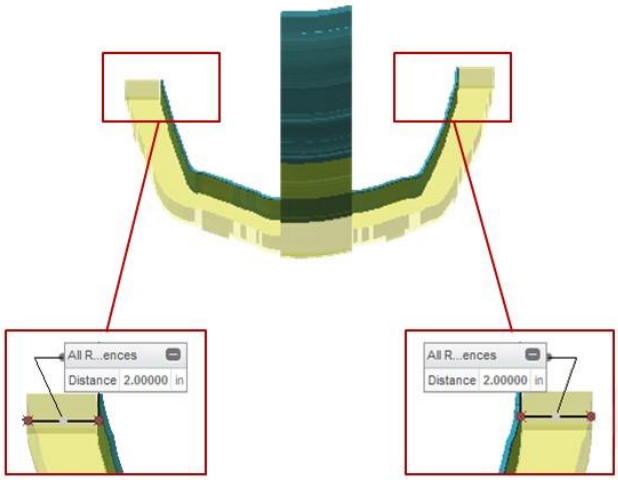


Rear View

295

Test #8: Clearance, Torso Boundary (PPE)

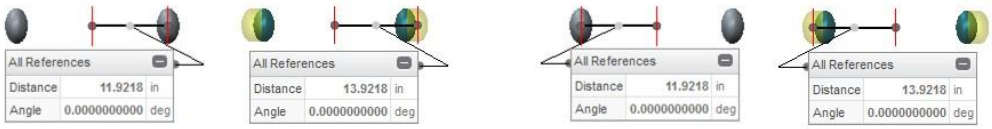




Side View **Top View**

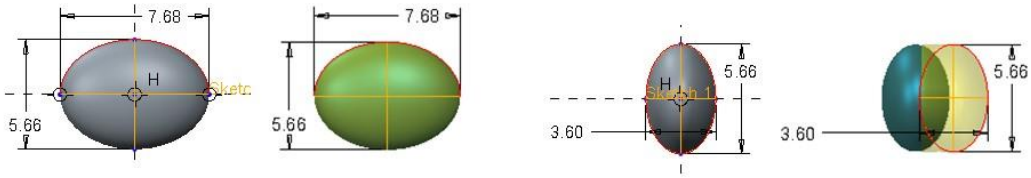
296

Test #8: Clearance, Elbow Boundary



Sample Calculation: $13.922\ in. - 11.922\ in. = 2.000\ in.\ clearance$

Rear View



Side View **Rear View**

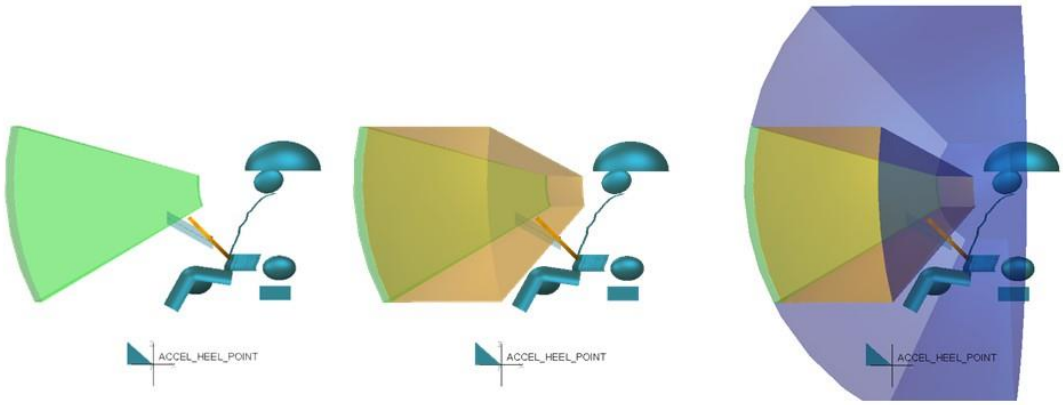
297

Test #8: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	PPE	13.3	29.0	No	SAE J826

Vision Zones

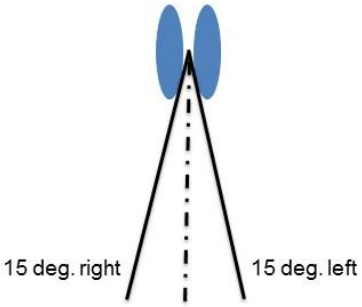
Vison zones are constructed geometrically; no calculations are involved.



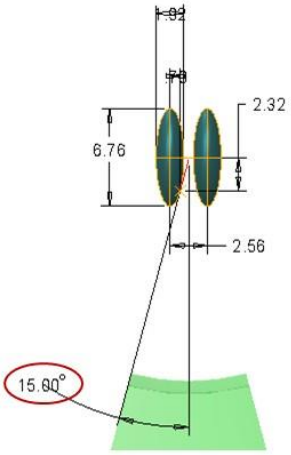
Primary Zone Secondary Zone Tertiary Zone

298

Test #8: Primary Vision Zone



Top View

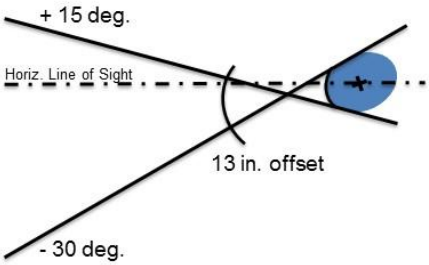


Intent

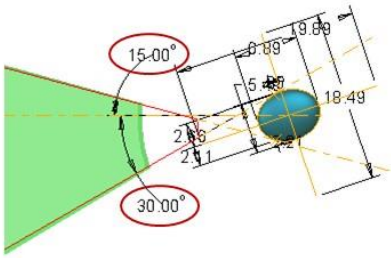
CAD Implementation

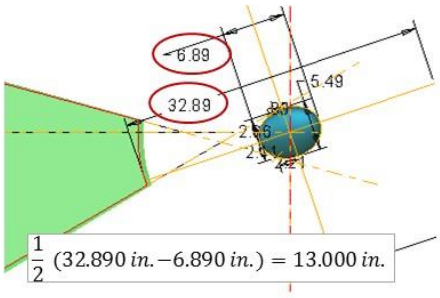
299

Test #8: Primary Vision Zone (cont.)



Side View



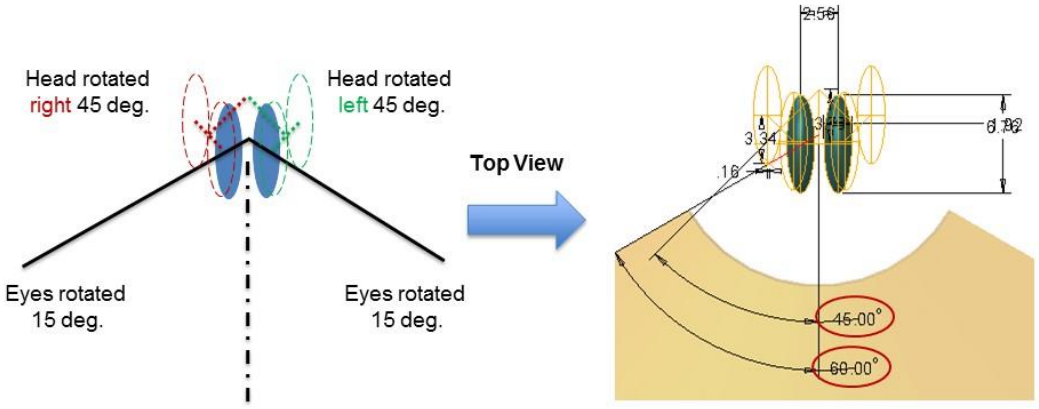


Intent

CAD Implementation

300

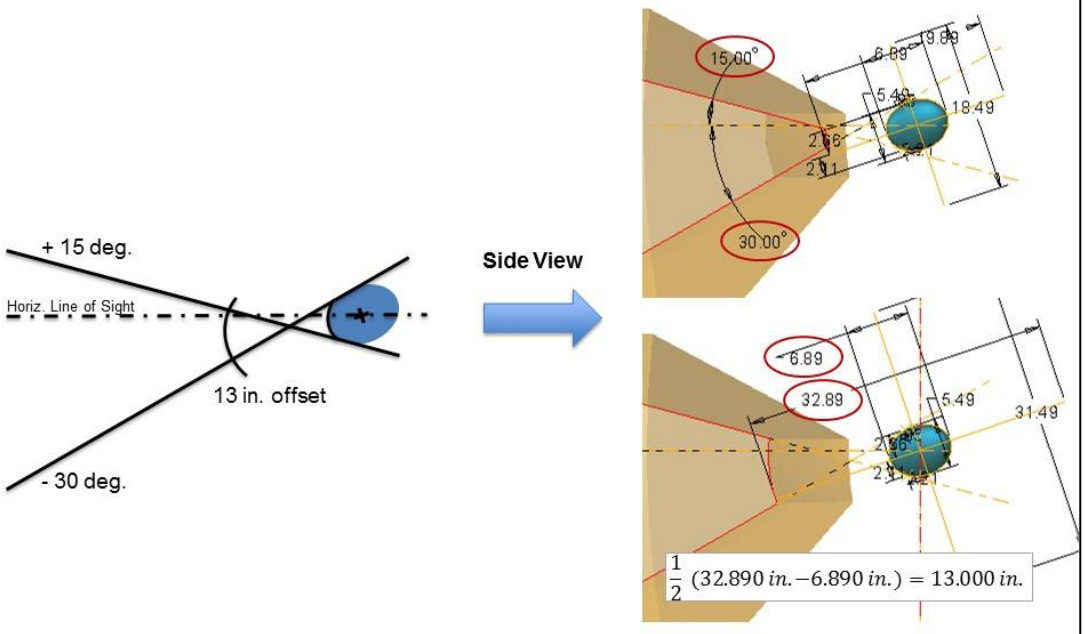
Test #8: Secondary Vision Zone



Intent CAD Implementation

301

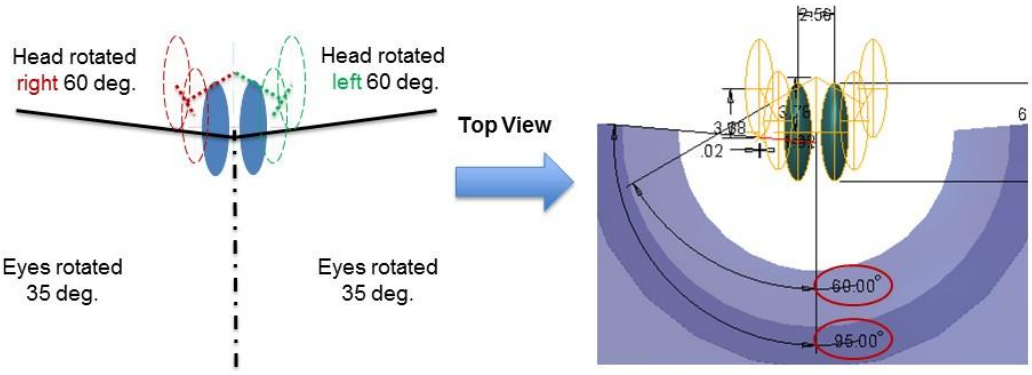
Test #8: Secondary Vision Zone (cont.)



Intent CAD Implementation

302

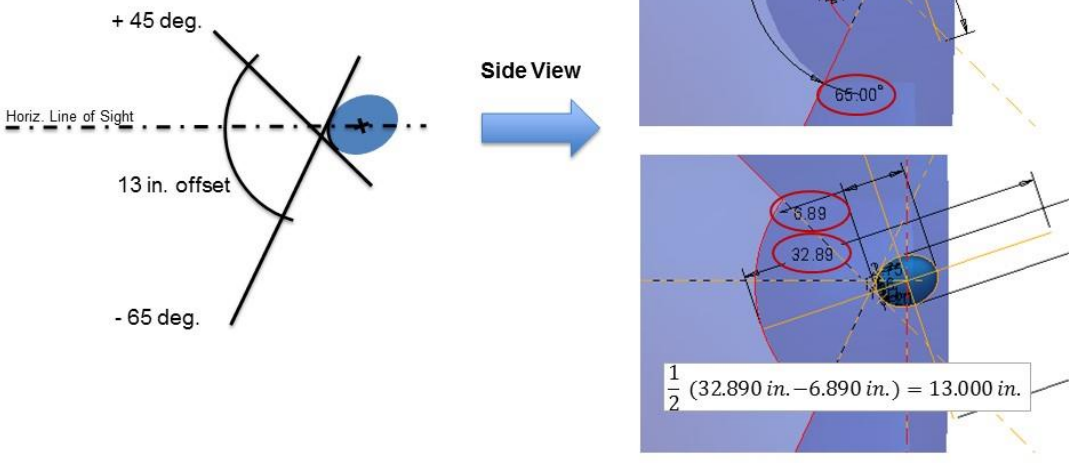
Test #8: Tertiary Vision Zone



Intent **CAD Implementation**

303

Test #8: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

304

Test #8: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	PPE	13.3	29.0	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

305

Test #8: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

306

Test #8: Small Overall Female

UMTRI Spreadsheet Calculations*

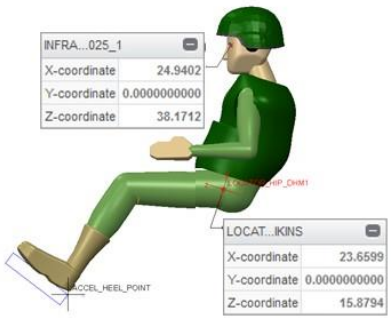
	ACU	PPE	ENC			
Hip re AHP X	601.0	601.0	618.6	→	23.660	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	24.940	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.660	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	24.940	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

307

Test #8: Small Overall Male

UMTRI Spreadsheet Calculations*

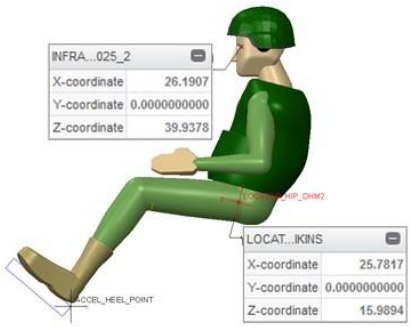
	ACU	PPE	ENC			
Hip re AHP X	654.9	654.9	672.5	→	25.782	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	26.191	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.782	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	26.191	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

308

Test #8: Average Size Male

UMTRI Spreadsheet Calculations*

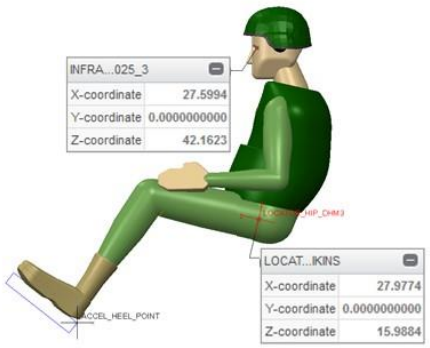
	ACU	PPE	ENC			
Hip re AHP X	710.6	710.6	728.2	→	27.977	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	27.599	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	27.977	in
POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_EYE_X	27.599	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

309

Test #8: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

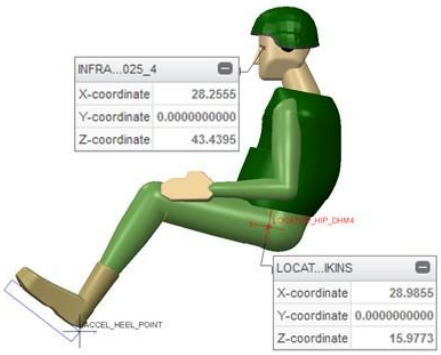
	ACU	PPE	ENC			
Hip re AHP X	736.2	736.2	753.8	→	28.985	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	28.255	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.986	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	28.256	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

310

Test #8: Longest Torso Male

UMTRI Spreadsheet Calculations*

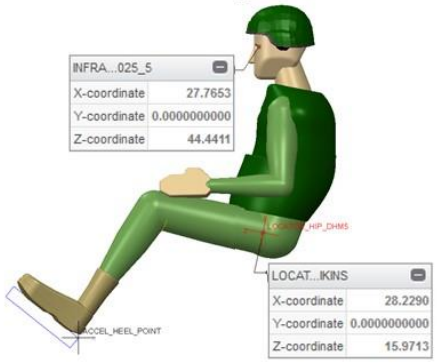
	ACU	PPE	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.229	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	27.765	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.229	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	27.765	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry



Side View

Front View

311

Test #8: Longest Legs Male

UMTRI Spreadsheet Calculations*

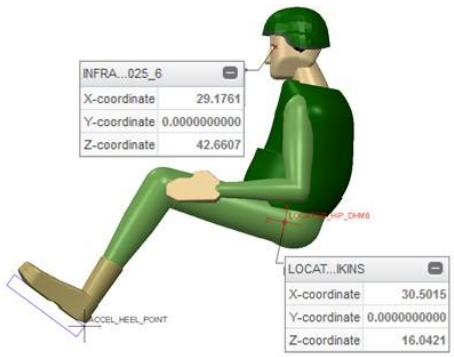
	ACU	PPE	ENC			
Hip re AHP X	774.7	774.7	792.3	→	30.501	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	29.176	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.502	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	29.176	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

312

Test #8: Large Overall Male

UMTRI Spreadsheet Calculations*

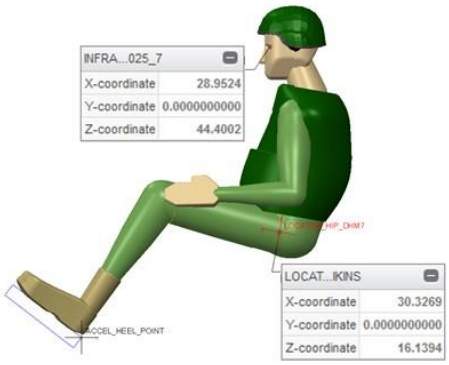
	ACU	PPE	ENC			
Hip re AHP X	770.3	770.3	787.9	→	30.327	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	28.952	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.327	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	28.952	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

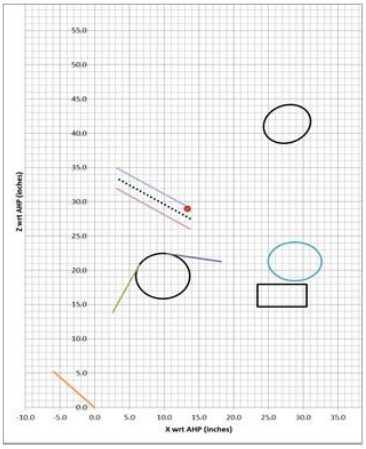
313

10.7.9 TEST #9 – VARY GENDER MIX AND ENSEMBLE

Test #9: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ACU	13.3	29.0	No	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

314

Test #9: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	26.947	in	26.947	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.319	in	16.319	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	16.510	deg	16.507	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.708	deg	26.712	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	27.668	in	27.668	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.365	in	41.365	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary
The ACU ensemble does not include a helmet

Knee Boundary	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	9.796	in	9.796	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg

Torso Boundary
A torso boundry is not provided when the ACU ensemble is chosen

Elbow Boundary	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	28.796	in	28.796	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	11.048	in	11.048	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	21.296	in	21.296	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

315

Test #9: Surrogate Steering Wheel

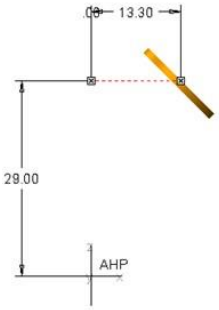
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

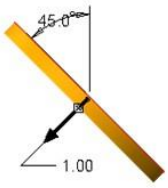
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

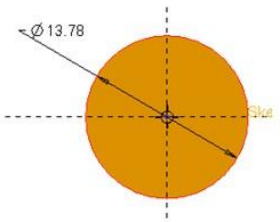
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

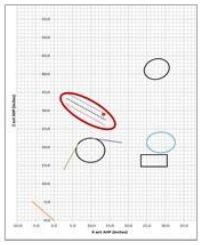
Side View **Steering Wheel Geometry**

316

Test #9: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

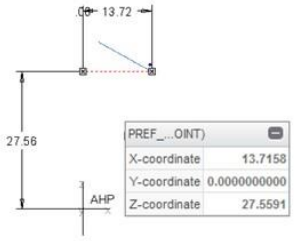
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	13.716	27.559
Preference Line Endpoint, Max	3.151	33.465



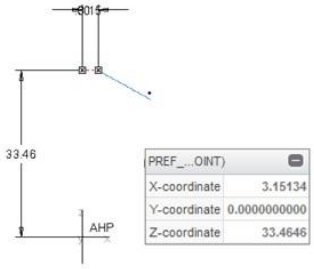
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	13.716	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.151	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



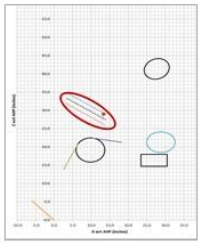
Preference Line Endpoint, Max

317

Test #9: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

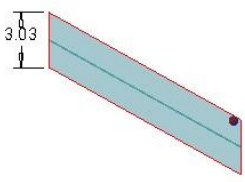
	L11 (in)	H17 (in)	
Upper Rear	13.716	29.074	←
Upper Front	3.151	34.980	
Lower Rear	13.716	26.044	←
Lower Front	3.151	31.949	



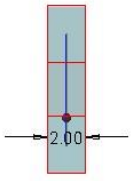
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

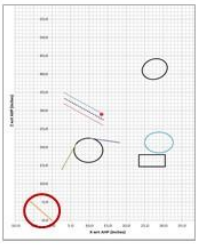
$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

*Given value, not calculated

318

Test #9: Accelerator Plane Angle (APA)



UMTRI Spreadsheet Calculations

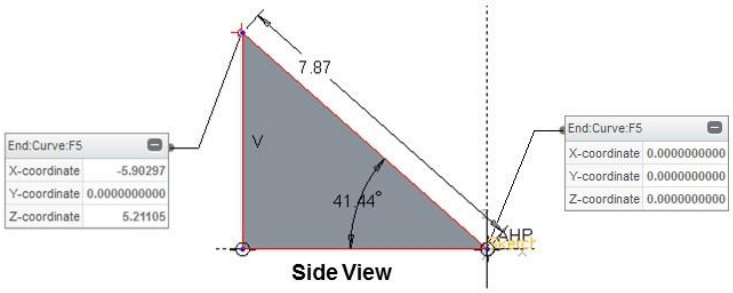
Accelerator Plane Angle (APA) 41.438 deg

	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211

TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG	41.438	deg

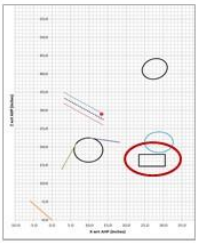
TARDEC CAD Model Geometry



Side View

319

Test #9: Seat Track Travel Range



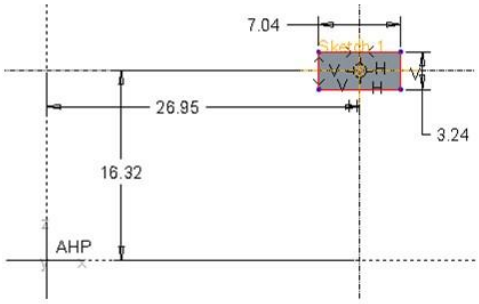
UMTRI Spreadsheet Calculations

Center of Travel (X)	26.947	in
Center of Travel (Z)	16.319	in
Fore-Aft Travel (X)	7.044	in
Vertical Travel (Z)	3.234	in

TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	26.947	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.319	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in
SEAT_POSITION_VERTICAL_TRAVEL	3.235	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 50.0 %
Ensemble: ACU (Advanced Combat Uniform)

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: FALSE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.0 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 26.9 in., Z = 16.3 in.)

320

Test #9: Seat Back Angle

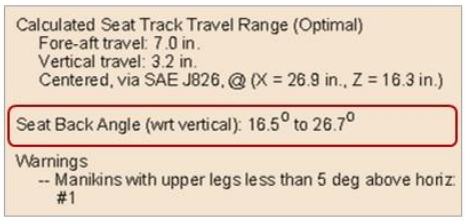
UMTRI Spreadsheet Calculations

Front of Range	16.510 deg
Rear of Range	26.708 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	16.507	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	26.712	deg

TARDEC CAD Model Geometry

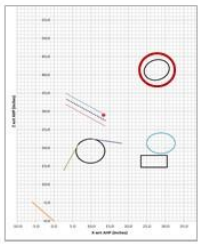


321

Test #9: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	27.668	1.280*	41.365
Left	27.668	-1.280*	41.365



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.889	in
Axis Length (Z')	→	5.484	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.643	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		27.668	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		41.365	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.890	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.486	in

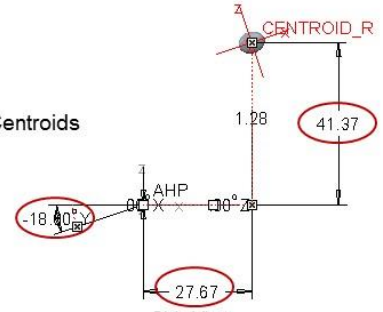
*Given value, not calculated

322

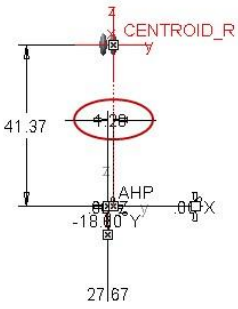
Test #9: Eyellipse (cont.)

TARDEC CAD Model Geometry

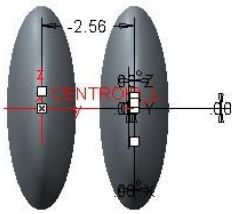
Centroids



Side View

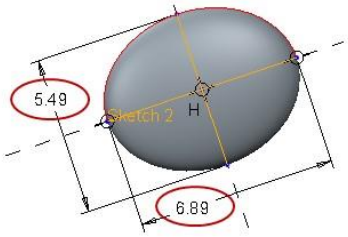


Rear View

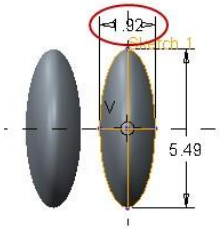


Rear View

Axis Lengths



Side View



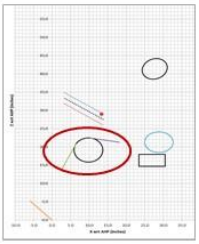
Rear View (Rotated)

323

Test #9: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	9.796	6.817	19.163
Left	9.796	-6.817	19.163



Side View of Knee Contours (X, Z)		
Axis Length (X)	7.753	in
Axis Length (Z)	6.615	in
Rear View of Knee Contours (Y, Z)		
Axis Length (Y)	8.895	in
Axis Length (Z)	6.615	in
Leg Segment Angle wrt Vertical	29.013	deg
Thigh Segment Angle wrt Horizontal	8.489	deg

TARDEC CAD Model Calculations

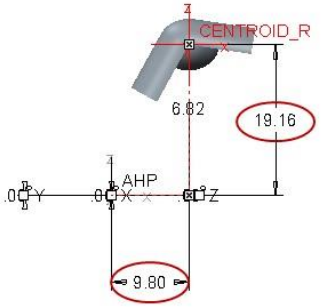
KNEE_CONTOUR_WEIGHTED_CENT_X	9.796	in
KNEE_CONTOUR_WEIGHTED_CENT_Y	6.817	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.754	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.896	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in
KNEE_SHIN_ANGLE	29.013	deg
KNEE_THIGH_ANGLE	8.489	deg

324

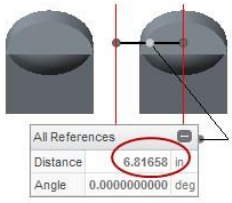
Test #9: Knee Boundary (cont.)

TARDEC CAD Model Result

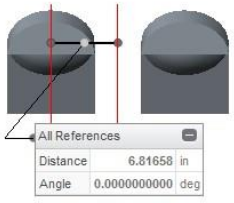
Centroids



Side View

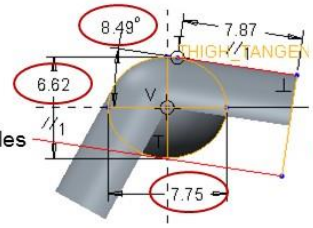


Rear View

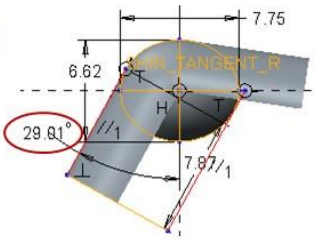


Rear View

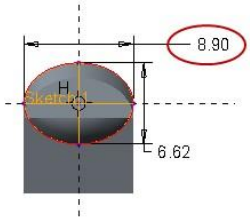
Axis Lengths
Shin/Thigh Angles



Side View



Side View



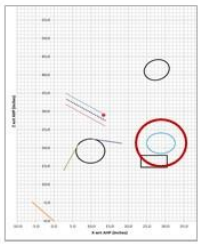
Rear View

325

Test #9: Elbow Boundary

UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	28.796	11.048	21.296
Left	28.796	-11.048	21.296



Side View of Elbow Contours (X, Z)

Axis Length (X)	→	7.680 in
Axis Length (Z)	→	5.652 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	→	3.599 in
Axis Length (Z)	→	5.652 in

TARDEC CAD Model Calculations

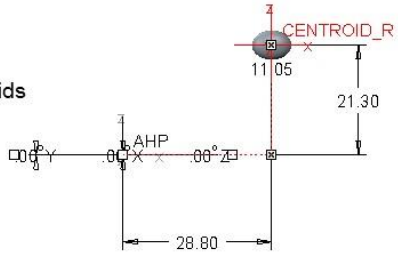
ELBOW_WEIGHTED_CENT_X		28.796	in
ELBOW_WEIGHTED_CENT_Y		11.048	in
ELBOW_WEIGHTED_CENT_Z		21.296	in
ELBOW_X_AXIS_LENGTH	→	7.681	in
ELBOW_Y_AXIS_LENGTH	→	3.599	in
ELBOW_Z_AXIS_LENGTH	→	5.655	in

326

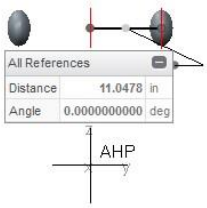
Test #9: Elbow Boundary (cont.)

TARDEC CAD Model Result

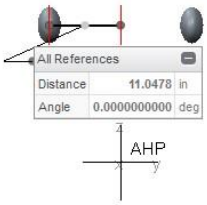
Centroids



Side View

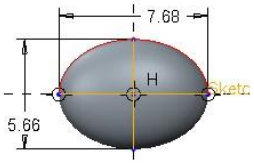


Rear View

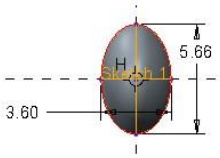


Rear View

Axis Lengths



Side View



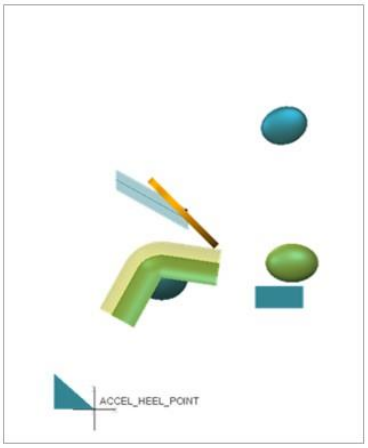
Rear View

327

Test #9: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ACU	13.3	29.0	No	SAE J826

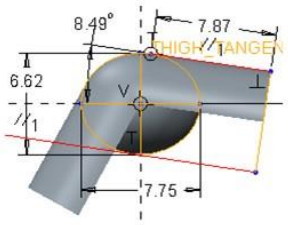
Clearance (2.0 inches), Shown in Yellow

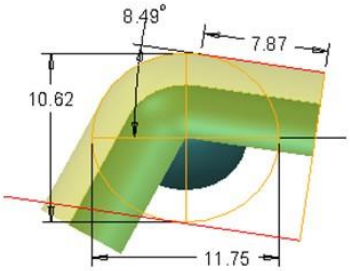


TARDEC CAD Model

328

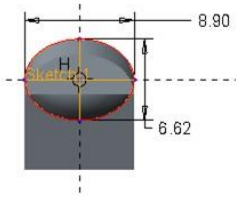
Test #9: Clearance, Knee Boundary

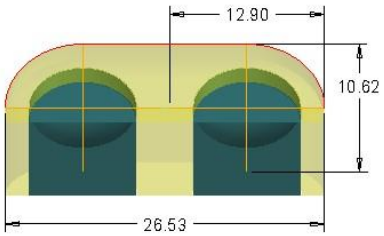




Sample Calculation: $\frac{1}{2}(10.615\,in. - 6.615\,in.) = 2.000\,in.\,clearance$

Side View

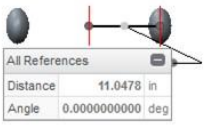


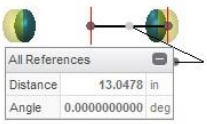


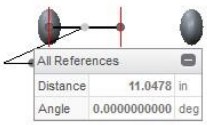
Rear View

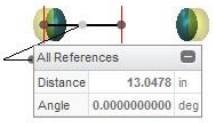
329

Test #9: Clearance, Elbow Boundary



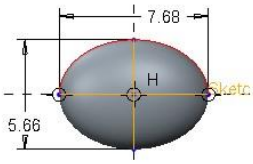


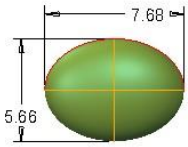


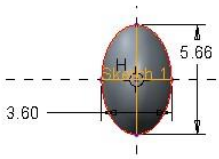


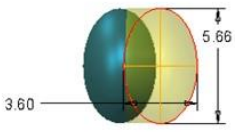
Sample Calculation: $13.048\,in. - 11.048\,in. = 2.000\,in.\,clearance$

Rear View









Side View **Rear View**

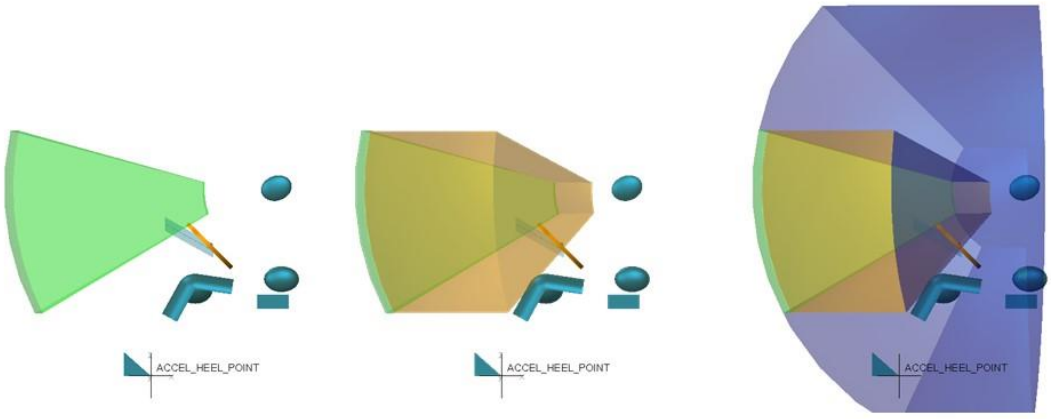
330

Test #9: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ACU	13.3	29.0	No	SAE J826

Vision Zones

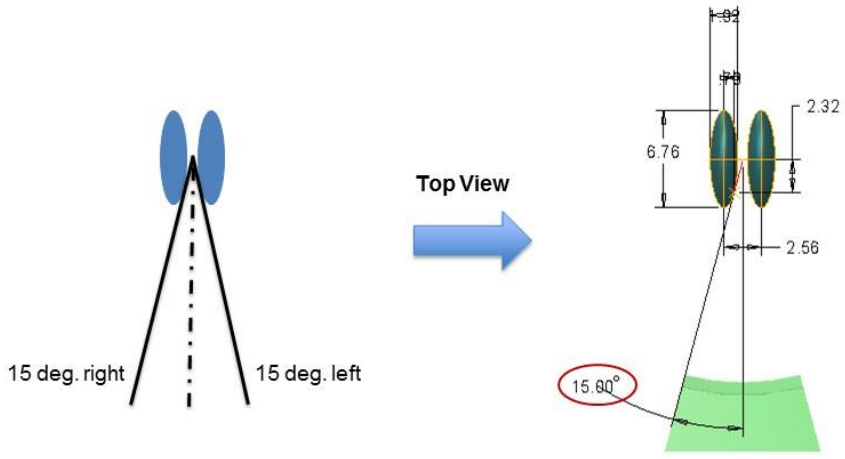
Vison zones are constructed geometrically; no calculations are involved.



Primary Zone | Secondary Zone | Tertiary Zone

331

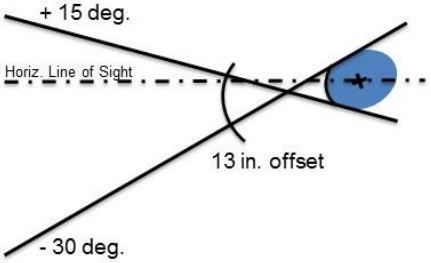
Test #9: Primary Vision Zone



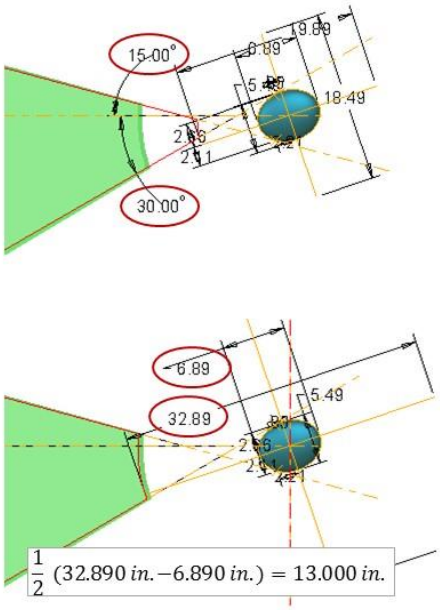
Intent **CAD Implementation**

332

Test #9: Primary Vision Zone (cont.)



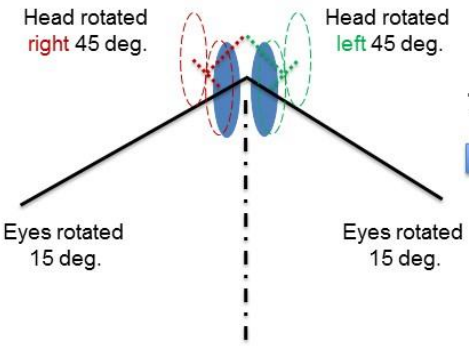
Side View



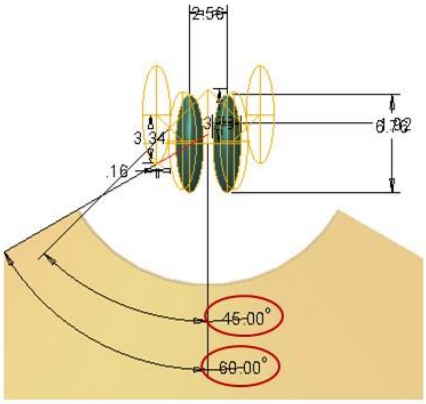
Intent | CAD Implementation

333

Test #9: Secondary Vision Zone



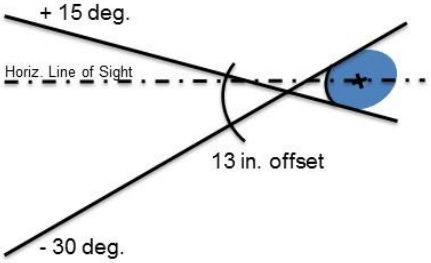
Top View



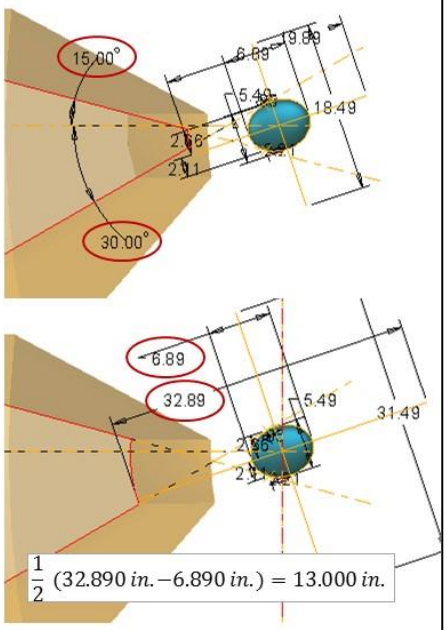
Intent | CAD Implementation

334

Test #9: Secondary Vision Zone (cont.)



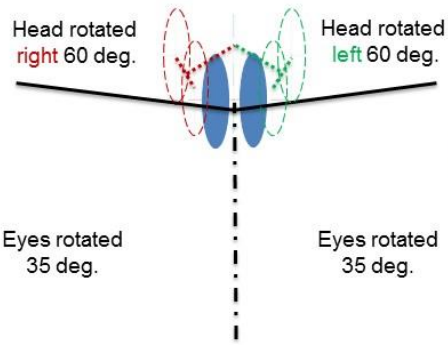
Side View



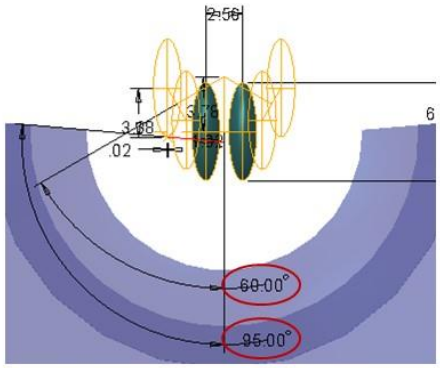
Intent **CAD Implementation**

335

Test #9: Tertiary Vision Zone



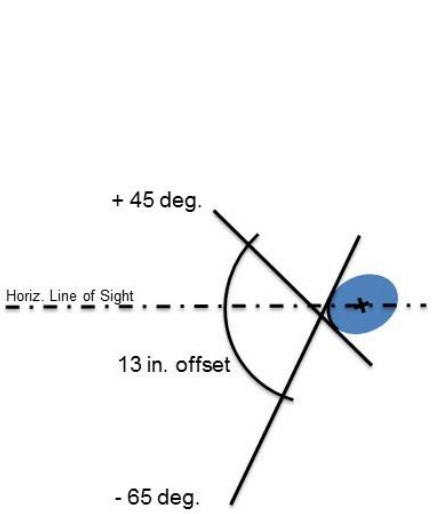
Top View



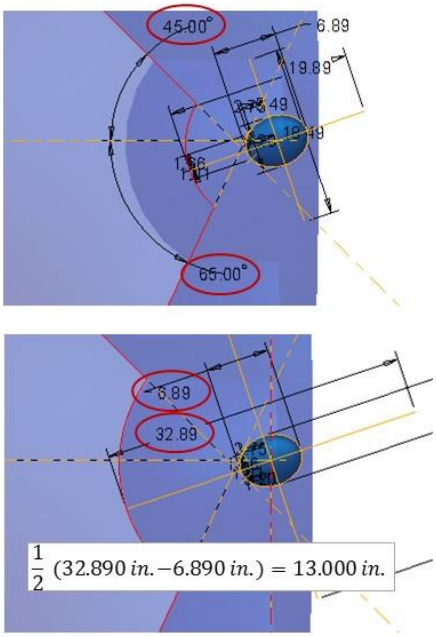
Intent **CAD Implementation**

336

Test #9: Tertiary Vision Zone (cont.)



Side View



Intent | CAD Implementation

337

Test #9: Vary Gender Mix and Ensemble

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ACU	13.3	29.0	No	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

338

Test #9: Numerical Results, Manikin Positioning

	UMTRI Value		TARDEC Value		Difference	
Small Overall Female						
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	26.357	in	26.357	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	27.608	in	27.608	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	29.017	in	29.017	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	29.673	in	29.673	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	29.183	in	29.183	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	30.593	in	30.593	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	30.370	in	30.370	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

339

Test #9: Small Overall Female

UMTRI Spreadsheet Calculations*

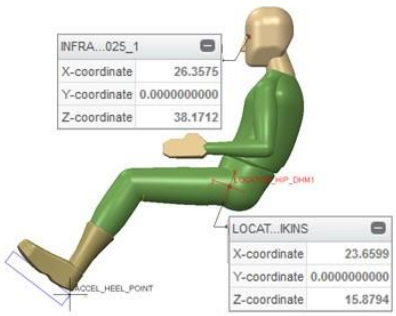
	ACU	PPE	ENC			
Hip re AHP X	601.0	601.0	618.6	→	23.660	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	26.357	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.660	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	26.357	in
POSTURE_DHM1_EYE_Z	38.171	in

TARDEC CAD Model Geometry



Side View

Front View

340

Test #9: Small Overall Male

UMTRI Spreadsheet Calculations*

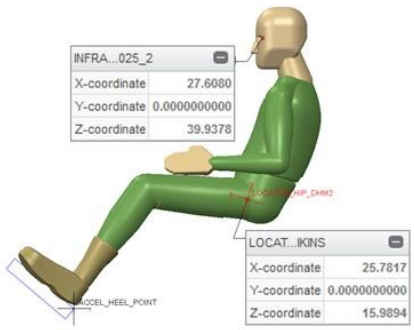
	ACU	PPE	ENC			
Hip re AHP X	654.9	654.9	672.5	→	25.782	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	27.608	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.782	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	27.608	in
POSTURE_DHM2_EYE_Z	39.938	in

TARDEC CAD Model Geometry



Side View

Front View

341

Test #9: Average Size Male

UMTRI Spreadsheet Calculations*

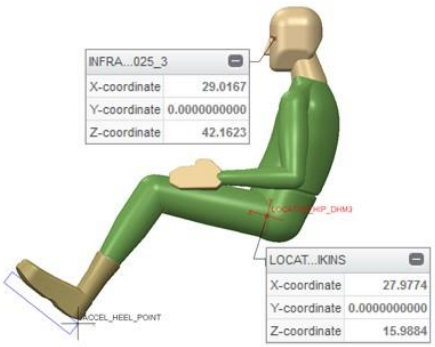
	ACU	PPE	ENC			
Hip re AHP X	710.6	710.6	728.2	→	27.977	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	29.017	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	27.977	in
POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_EYE_X	29.017	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

342

Test #9: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

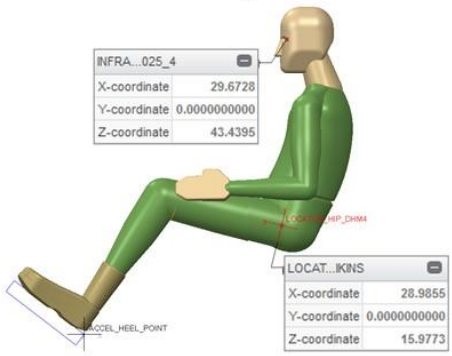
	ACU	PPE	ENC			
Hip re AHP X	736.2	736.2	753.8	→	28.985	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	29.673	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.986	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	29.673	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

343

Test #9: Longest Torso Male

UMTRI Spreadsheet Calculations*

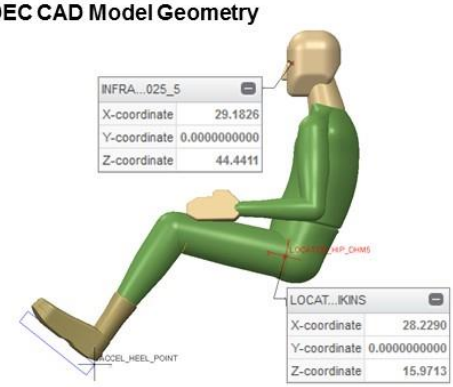
	ACU	PPE	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.229	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	29.183	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.229	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	29.183	in
POSTURE_DHM5_EYE_Z	44.441	in

TARDEC CAD Model Geometry



Side View

Front View

344

Test #9: Longest Legs Male

UMTRI Spreadsheet Calculations*

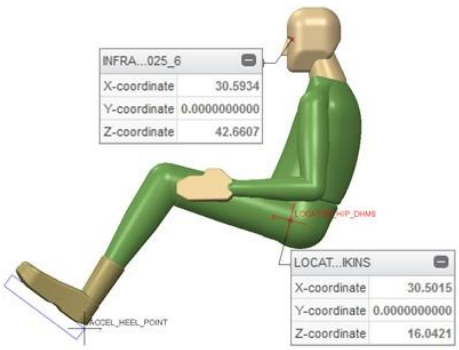
	ACU	PPE	ENC			
Hip re AHP X	774.7	774.7	792.3	→	30.501	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	30.593	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.502	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	30.593	in
POSTURE_DHM6_EYE_Z	42.661	in

TARDEC CAD Model Geometry



Side View

Front View

345

Test #9: Large Overall Male

UMTRI Spreadsheet Calculations*

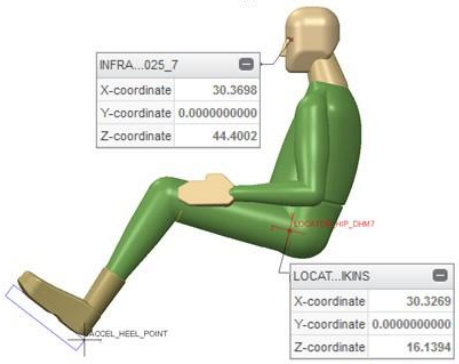
	ACU	PPE	ENC			
Hip re AHP X	770.3	770.3	787.9	→	30.327	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	30.370	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

*Relevant values (highlighted) have been converted from millimeters to inches

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.327	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	30.370	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

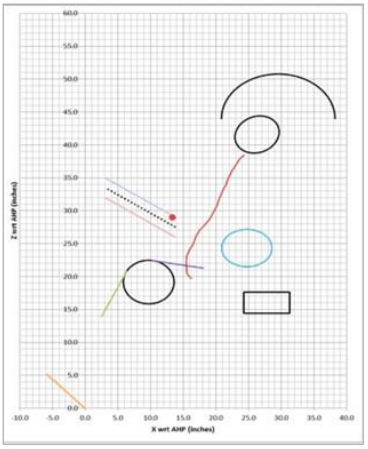
346

10.7.10 TEST #10 – VARY GENDER MIX, ENSEMBLE, AND PROVIDE HYDRATION PACK RELIEF

Test #10: Vary Gender Mix, Ensemble, and Provide Hydration Pack Relief

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ENC	13.3	29.0	Yes	SAE J826

Basic Accommodation



UMTRI Spreadsheet

TARDEC CAD Model

347

Test #10: Numerical Results, Accommodation

Surrogate Steering Wheel	UMTRI Value		TARDEC Value		Difference	
STEERING_WHEEL_X	13.300	in	13.300	in	0.000	in
STEERING_WHEEL_Z	29.000	in	29.000	in	0.000	in
Steering Wheel Preference Line						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_FWD_X	13.716	in	13.716	in	0.000	in
STRG_WHL_FWD_Z	27.559	in	27.559	in	0.000	in
STRG_WHL_RWD_X	3.151	in	3.151	in	0.000	in
STRG_WHL_RWD_Z	33.465	in	33.465	in	0.000	in
Steering Wheel Preference Zone						
	UMTRI Value		TARDEC Value		Difference	
STRG_WHL_ZONE_Z	1.515	in	1.516	in	0.001	in
STRG_WHL_ZONE_Y	N/A		1.000	in	N/A	
Accelerator Plane Angle (APA)						
	UMTRI Value		TARDEC Value		Difference	
ACCEL_PEDAL_PLANE_ANG	41.438	deg	41.438	deg	0.000	deg
Origin (X)	0.000	in	0.000	in	0.000	in
Origin (Z)	0.000	in	0.000	in	0.000	in
BOFRP (X)	-5.903	in	-5.903	in	0.000	in
BOFRP (Z)	5.211	in	5.211	in	0.000	in
Seat Track Travel Range						
	UMTRI Value		TARDEC Value		Difference	
SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in	27.766	in	0.000	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.023	in	16.023	in	0.000	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in	7.044	in	0.000	in
SEAT_POSITION_VERTICAL_TRAVEL	3.234	in	3.235	in	0.001	in
Seat Back Angle						
	UMTRI Value		TARDEC Value		Difference	
SEAT_BACK_ANGLE_LOWER_QUANTILE	19.110	deg	19.107	deg	0.004	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	29.308	deg	29.312	deg	0.004	deg
Eyellipse						
	UMTRI Value		TARDEC Value		Difference	
EYELLIPSE_CENTROID_X	26.271	in	26.271	in	0.000	in
EYELLIPSE_CENTROID_Y (+/-)	1.280	in	1.280	in	0.000	in
EYELLIPSE_CENTROID_Z	41.582	in	41.582	in	0.000	in
EYELLIPSE_ANGLE_REL_X	18.600	deg	18.600	deg	0.000	deg
EYELLIPSE_X_AXIS_LENGTH	6.889	in	6.890	in	0.001	in
EYELLIPSE_Y_AXIS_LENGTH	1.917	in	1.918	in	0.001	in
EYELLIPSE_Z_AXIS_LENGTH	5.484	in	5.486	in	0.002	in

Helmet Boundary	UMTRI Value		TARDEC Value		Difference	
HELMET_CONTOUR_CENTROID_X	29.515	in	29.515	in	0.000	in
HELMET_CONTOUR_CENTROID_Y (+/-)	2.185	in	2.185	in	0.000	in
HELMET_CONTOUR_CENTROID_Z	43.999	in	43.999	in	0.000	in
HELMET_CONTOUR_X_AXIS_LENGTH	17.358	in	17.359	in	0.001	in
HELMET_CONTOUR_Y_AXIS_LENGTH	9.515	in	9.517	in	0.001	in
HELMET_CONTOUR_Z_AXIS_LENGTH	13.548	in	13.550	in	0.002	in
Knee Boundary						
	UMTRI Value		TARDEC Value		Difference	
KNEE_CONTOUR_WEIGHTED_CENT_X	9.709	in	9.709	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Y (+/-)	6.817	in	6.817	in	0.000	in
KNEE_CONTOUR_WEIGHTED_CENT_Z	19.163	in	19.163	in	0.000	in
KNEE_CONTOUR_X_AXIS_LENGTH	7.753	in	7.754	in	0.001	in
KNEE_CONTOUR_Y_AXIS_LENGTH	8.895	in	8.896	in	0.000	in
KNEE_CONTOUR_Z_AXIS_LENGTH	6.615	in	6.615	in	0.000	in
KNEE_SHIN_ANGLE	29.013	deg	29.013	deg	0.000	deg
KNEE_THIGH_ANGLE	8.489	deg	8.489	deg	0.000	deg
Torso Boundary						
	UMTRI Value		TARDEC Value		Difference	
TORSO_WEIGHTED_REF_PT_ENC_Z	15.983	in	15.983	in	0.000	in
TORSO_WEIGHTED_REF_PT_ENC_X	27.795	in	27.795	in	0.000	in
Elbow Boundary						
	UMTRI Value		TARDEC Value		Difference	
ELBOW_WEIGHTED_CENT_X	24.717	in	24.717	in	0.000	in
ELBOW_WEIGHTED_CENT_Y (+/-)	14.276	in	14.276	in	0.000	in
ELBOW_WEIGHTED_CENT_Z	24.331	in	24.331	in	0.000	in
ELBOW_X_AXIS_LENGTH	7.680	in	7.681	in	0.000	in
ELBOW_Y_AXIS_LENGTH	3.599	in	3.599	in	0.000	in
ELBOW_Z_AXIS_LENGTH	5.652	in	5.655	in	0.003	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.003 inches
0.004 degrees

Values in agreement

348

Test #10: Surrogate Steering Wheel

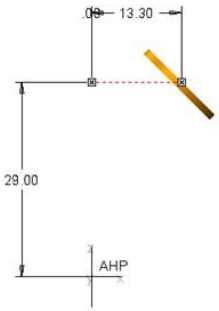
UMTRI Spreadsheet Calculations

	L11 (in)	H17 (in)
Steering Wheel Point (SWP)	13.300	29.000

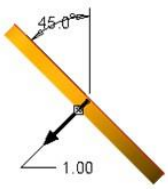
TARDEC CAD Model Calculations

STEERING_WHEEL_X	13.300	in
STEERING_WHEEL_Z	29.000	in

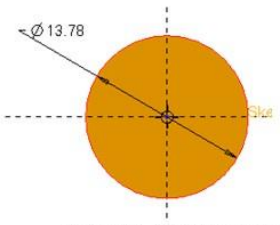
TARDEC CAD Model Geometry



Side View



Side View



Normal to Steering Wheel

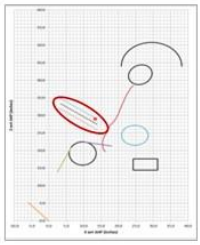
Side View **Steering Wheel Geometry**

349

Test #10: Steering Wheel Preference Line

UMTRI Spreadsheet Calculations

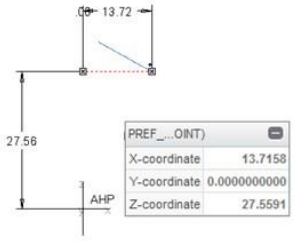
	L11 (in)	H17 (in)
Preference Line Endpoint, Min	13.716	27.559
Preference Line Endpoint, Max	3.151	33.465



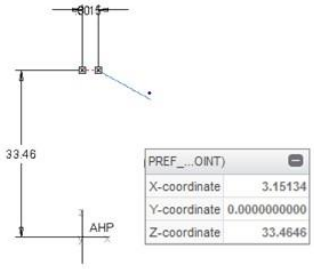
TARDEC CAD Model Calculations

STRG_WHL_FWD_X	13.716	in
STRG_WHL_FWD_Z	27.559	in
STRG_WHL_RWD_X	3.151	in
STRG_WHL_RWD_Z	33.465	in

TARDEC CAD Model Geometry



Preference Line Endpoint, Min



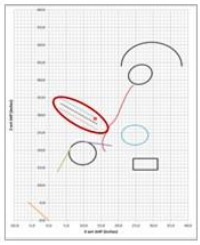
Preference Line Endpoint, Max

350

Test #10: Steering Wheel Preference Zone

UMTRI Spreadsheet Calculations

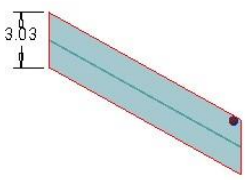
	L11 (in)	H17 (in)	
Upper Rear	13.716	29.074	←
Upper Front	3.151	34.980	
Lower Rear	13.716	26.044	←
Lower Front	3.151	31.949	



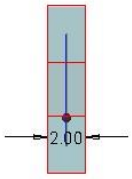
TARDEC CAD Model Calculations

STRG_WHL_ZONE_Z	1.516	in	} These values represent half of the zone.
STRG_WHL_ZONE_Y	1.000*	in	

TARDEC CAD Model Geometry



Side View



Rear View

$$29.074\ in. - 26.044\ in. = 3.030\ in.$$

$$\frac{1}{2}(3.030\ in.) = 1.515\ in.$$

*Given value, not calculated

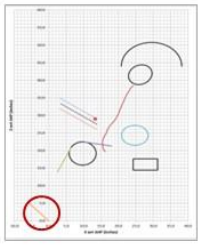
351

Test #10: Accelerator Plane Angle (APA)

UMTRI Spreadsheet Calculations

Accelerator Plane Angle (APA) 41.438 deg

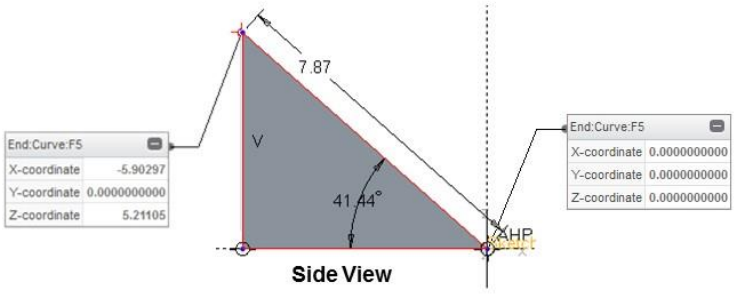
	X (in)	Z (in)
Origin	0.000	0.000
BOFRP	-5.903	5.211



TARDEC CAD Model Calculations

ACCEL_PEDAL_PLANE_ANG 41.438 deg

TARDEC CAD Model Geometry



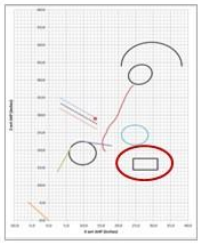
Side View

352

Test #10: Seat Track Travel Range

UMTRI Spreadsheet Calculations

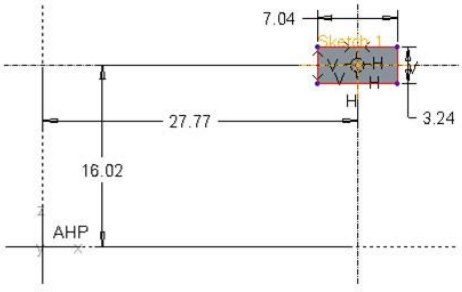
Center of Travel (X)	27.766	in
Center of Travel (Z)	16.023	in
Fore-Aft Travel (X)	7.044	in
Vertical Travel (Z)	3.234	in



TARDEC CAD Model Calculations

SEAT_POSITION_CTR_OF_TRAVEL_X	27.766	in
SEAT_POSITION_CTR_OF_TRAVEL_Z	16.023	in
SEAT_POSITION_FORE_AFT_TRAVEL	7.044	in
SEAT_POSITION_VERTICAL_TRAVEL	3.235	in

TARDEC CAD Model Geometry



Side View

*** TARDEC™ Fixed Heel Point (FHP): Driver ***

Target Accommodation: 90.0 %

Population Description
Fraction male: 50.0 %
Ensemble: ENC (PPE + Rifleman-like Gear)

Vehicle Description
Steering Wheel Point, X (wrt AHP): 13.3 in.
Steering Wheel Point, Z (wrt AHP): 29.0 in.

Consider hydration pack relief: TRUE

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.0 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.8 in., Z = 16.0 in.)

353

Test #10: Seat Back Angle

UMTRI Spreadsheet Calculations

Front of Range	19.110 deg
Rear of Range	29.308 deg

TARDEC CAD Model Calculations

SEAT_BACK_ANGLE_LOWER_QUANTILE	19.107	deg
SEAT_BACK_ANGLE_UPPER_QUANTILE	29.312	deg

TARDEC CAD Model Geometry

Calculated Seat Track Travel Range (Optimal)
Fore-aft travel: 7.0 in.
Vertical travel: 3.2 in.
Centered, via SAE J826, @ (X = 27.8 in., Z = 16.0 in.)

Seat Back Angle (wrt vertical): 19.1^{o} to 29.3^{o}

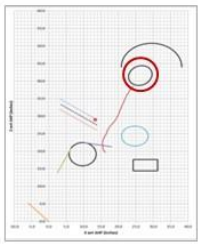
Warnings
-- Manikins with upper legs less than 5 deg above horiz: #1

354

Test #10: Eyellipse

UMTRI Spreadsheet Calculations

Eyellipse Centroids	X (in)	Y (in)	Z (in)
Right	26.271	1.280*	41.582
Left	26.271	-1.280*	41.582



Side View of Eyellipses (X, Z)			
Eyellipse Angle (X' Axis wrt Horizontal)		18.600*	deg
Axis Length (X')	→	6.889	in
Axis Length (Z')	→	5.484	in
Rear View of Eyellipses (Y, Z)			
Axis Length (Y)	→	1.917	in
Axis Length (Z)		5.643	in

TARDEC CAD Model Calculations

EYELLIPSE_CENTROID_X		26.271	in
EYELLIPSE_SPACING_Y		2.559*	in → $\frac{1}{2}(2.559\,in.) = 1.280\,in.$
EYELLIPSE_CENTROID_Z		41.582	in
EYELLIPSE_ANGLE_REL_X		18.600*	deg
EYELLIPSE_X_AXIS_LENGTH	→	6.890	in
EYELLIPSE_Y_AXIS_LENGTH	→	1.918	in
EYELLIPSE_Z_AXIS_LENGTH	→	5.486	in

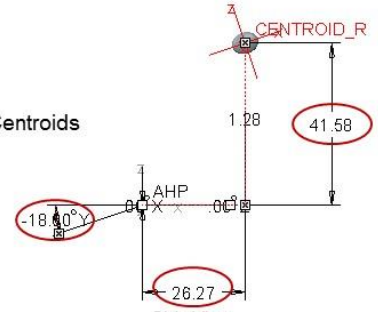
*Given value, not calculated

355

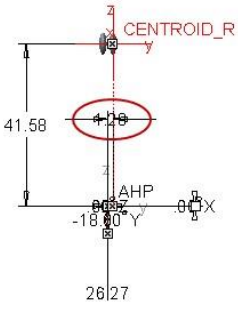
Test #10: Eyellipse (cont.)

TARDEC CAD Model Geometry

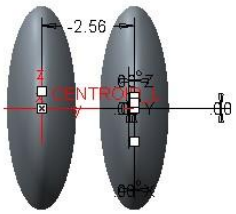
Centroids



Side View

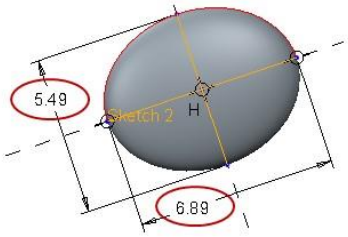


Rear View

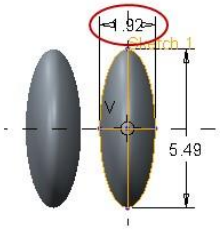


Rear View

Axis Lengths



Side View



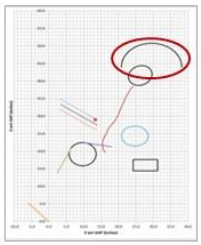
Rear View (Rotated)

356

Test #10: Helmet Boundary

UMTRI Spreadsheet Calculations

Construction Centroids	X (in)	Y (in)	Z (in)
Right	29.515	2.185*	43.999
Left	29.515	-2.185*	43.999



Side View of Helmet Contour (X, Z)			
Axis Length (X)	→	17.358	in
Axis Length (Z)	→	13.548	in
Rear View of Helmet Contour (Y, Z)			
Axis Length (Y)	→	9.515	in
Axis Length (Z)	→	13.548	in

TARDEC CAD Model Calculations

HELMET_CONTOUR_CENTROID_X		29.515	in
EYELLIPSE_SPACING_Y		2.559*	in
HEAD_TURN_Y		23.000*	mm
HELMET_CONTOUR_CENTROID_Z		43.999	in
HELMET_CONTOUR_X_AXIS_LENGTH	→	17.359	in
HELMET_CONTOUR_Y_AXIS_LENGTH	→	9.517	in
HELMET_CONTOUR_Z_AXIS_LENGTH	→	13.550	in

$$\frac{1}{2}(2.559\ in.) + 23.000\ mm = 2.185\ in.$$

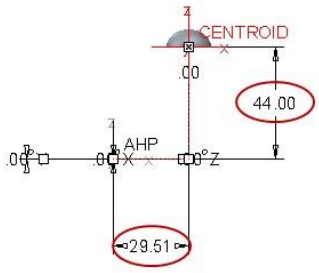
*Given value, not calculated

357

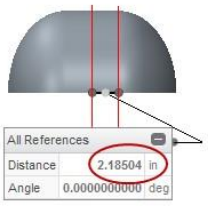
Test #10: Helmet Boundary (cont.)

TARDEC CAD Model Result

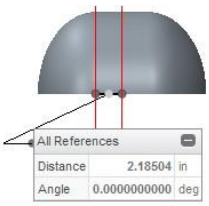
Centroids



Side View

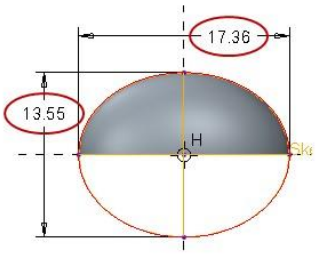


Rear View

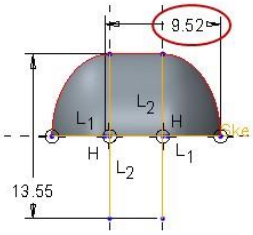


Rear View

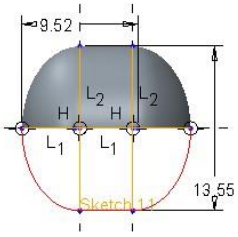
Axis Lengths



Side View



Rear View



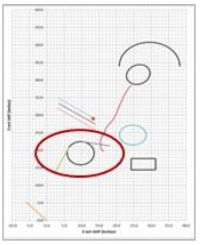
Rear View

358

Test #10: Knee Boundary

UMTRI Spreadsheet Calculations

Knee Centroids	X (in)	Y (in)	Z (in)
Right	9.709	6.817	19.163
Left	9.709	-6.817	19.163



Side View of Knee Contours (X, Z)			
Axis Length (X)	→	7.753	in
Axis Length (Z)	→	6.615	in
Rear View of Knee Contours (Y, Z)			
Axis Length (Y)	→	8.895	in
Axis Length (Z)	→	6.615	in
Leg Segment Angle wrt Vertical		29.013	deg
Thigh Segment Angle wrt Horizontal		8.489	deg

TARDEC CAD Model Calculations

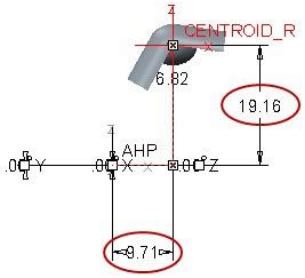
KNEE_CONTOUR_WEIGHTED_CENT_X		9.709	in
KNEE_CONTOUR_WEIGHTED_CENT_Y		6.817	in
KNEE_CONTOUR_WEIGHTED_CENT_Z		19.163	in
KNEE_CONTOUR_X_AXIS_LENGTH	→	7.754	in
KNEE_CONTOUR_Y_AXIS_LENGTH	→	8.896	in
KNEE_CONTOUR_Z_AXIS_LENGTH	→	6.615	in
KNEE_SHIN_ANGLE		29.013	deg
KNEE_THIGH_ANGLE		8.489	deg

359

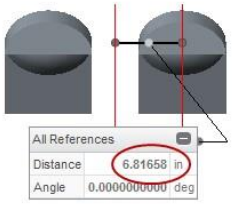
Test #10: Knee Boundary (cont.)

TARDEC CAD Model Result

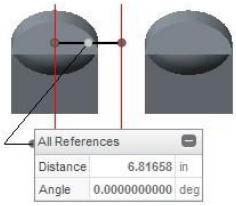
Centroids



Side View

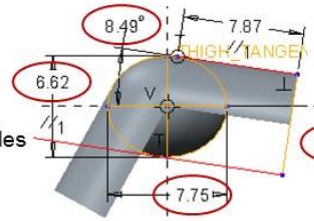


Rear View

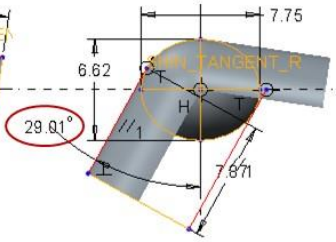


Rear View

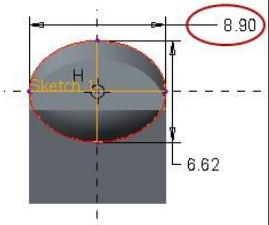
Axis Lengths
Shin/Thigh Angles



Side View



Side View

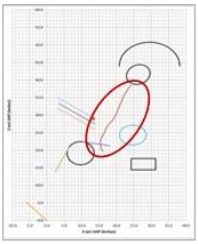


Rear View

Test #10: Torso Boundary (ENC)

UMTRI Spreadsheet Calculations

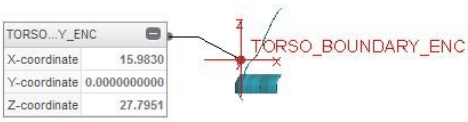
Mean Reference Point	X (in)	Z (in)
PPE	21.517	32.879
ENC	15.983	27.795



TARDEC CAD Model Calculations

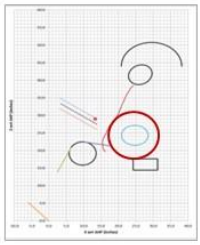
TORSO_WEIGHTED_REF_PT_ENC_X	15.983	in
TORSO_WEIGHTED_REF_PT_ENC_Z	27.795	in

TARDEC CAD Model Geometry



Side View

Test #10: Elbow Boundary



UMTRI Spreadsheet Calculations

Elbow Centroids	X (in)	Y (in)	Z (in)
Right	24.717	14.276	24.331
Left	24.717	-14.276	24.331

Side View of Elbow Contours (X, Z)

Axis Length (X)	→	7.680 in
Axis Length (Z)	→	5.652 in

Rear View of Elbow Contours (Y, Z)

Axis Length (Y)	→	3.599 in
Axis Length (Z)	→	5.652 in

TARDEC CAD Model Calculations

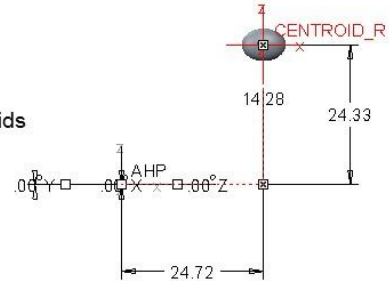
ELBOW_WEIGHTED_CENT_X		24.717	in
ELBOW_WEIGHTED_CENT_Y		14.276	in
ELBOW_WEIGHTED_CENT_Z		24.331	in
ELBOW_X_AXIS_LENGTH	→	7.681	in
ELBOW_Y_AXIS_LENGTH	→	3.599	in
ELBOW_Z_AXIS_LENGTH	→	5.655	in

362

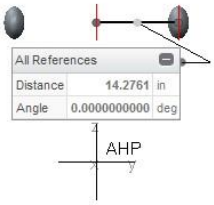
Test #10: Elbow Boundary (cont.)

TARDEC CAD Model Result

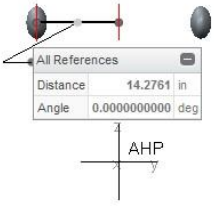
Centroids



Side View

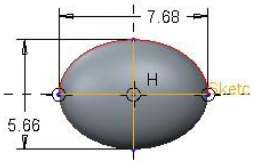


Rear View

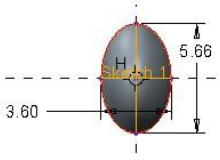


Rear View

Axis Lengths



Side View



Rear View

363

Test #10: Vary Gender Mix, Ensemble, and Provide Hydration Pack Relief

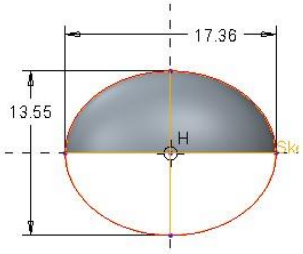
Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ENC	13.3	29.0	Yes	SAE J826

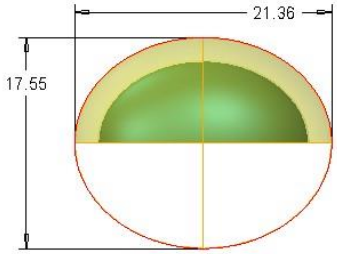
Clearance (2.0 inches), Shown in Yellow

TARDEC CAD Model

364

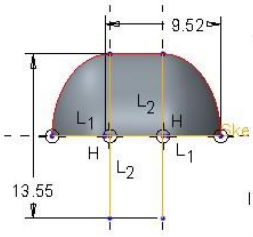
Test #10: Clearance, Helmet Boundary

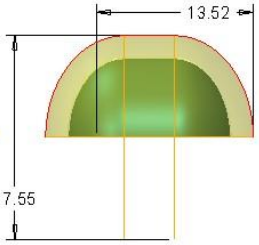


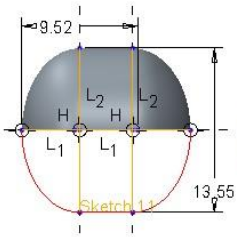


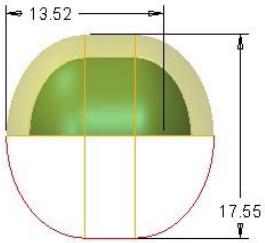
$$Sample\ Calculation: \frac{1}{2}\,(21.359\,in. - 17.359\,in.) = 2.000\,in.\,clearance$$

Side View





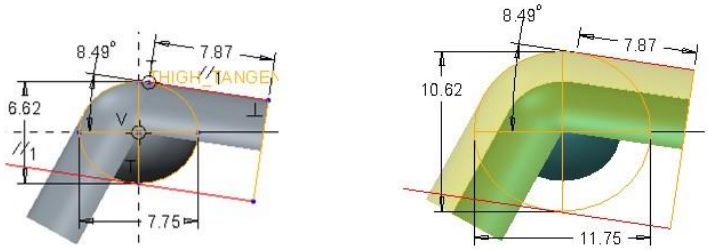




Rear View

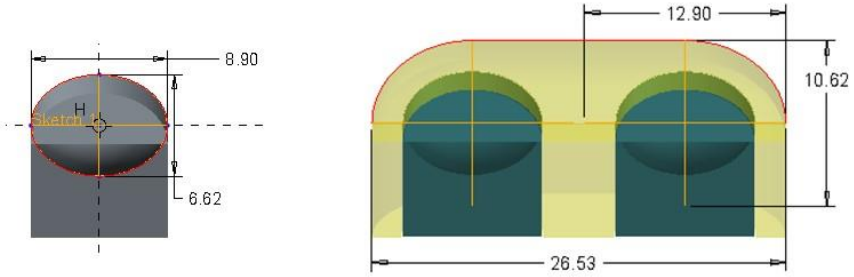
365

Test #10: Clearance, Knee Boundary



$$Sample\ Calculation: \frac{1}{2}\,(10.615\,in. - 6.615\,in.) = 2.000\,in.clearance$$

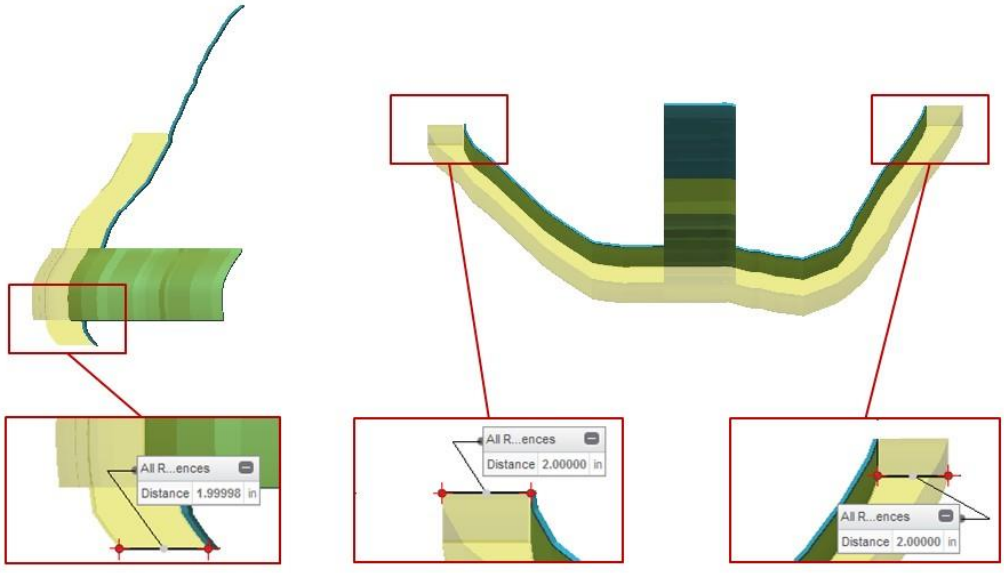
Side View



Rear View

366

Test #10: Clearance, Torso Boundary (ENC)



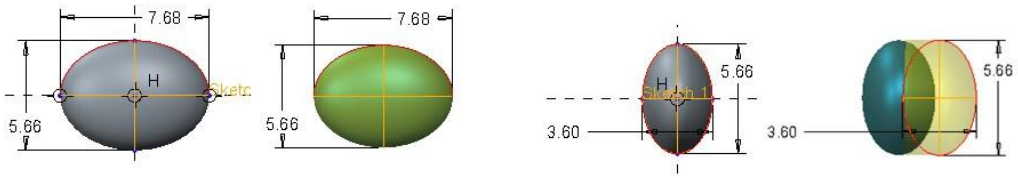
Side View **Top View**

367

Test #10: Clearance, Elbow Boundary

Sample Calculation: 16.276 *in.* − 14.276 *in.* = 2.000 *in. clearance*

Rear View



Side View **Rear View**

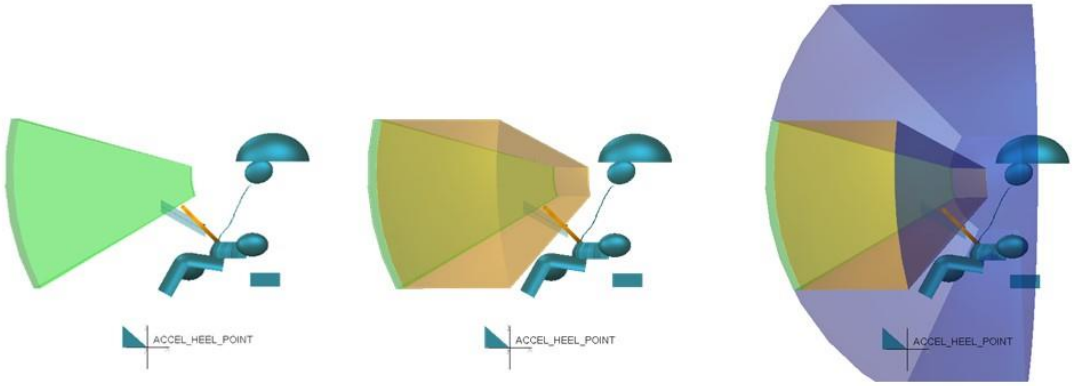
368

Test #10: Vary Gender Mix, Ensemble, and Provide Hydration Pack Relief

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ENC	13.3	29.0	Yes	SAE J826

Vision Zones

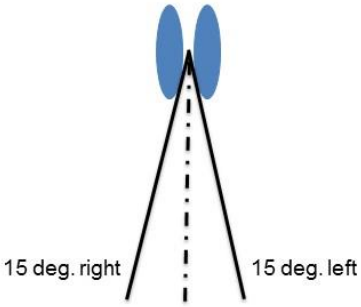
Vison zones are constructed geometrically; no calculations are involved.



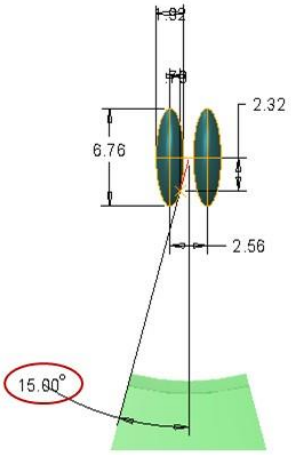
Primary Zone Secondary Zone Tertiary Zone

369

Test #10: Primary Vision Zone



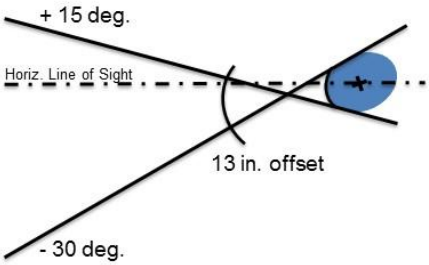
Top View



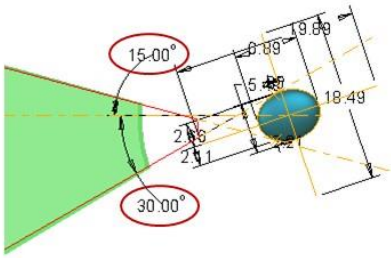
Intent | CAD Implementation

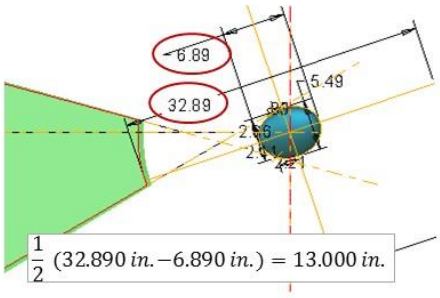
370

Test #10: Primary Vision Zone (cont.)



Side View

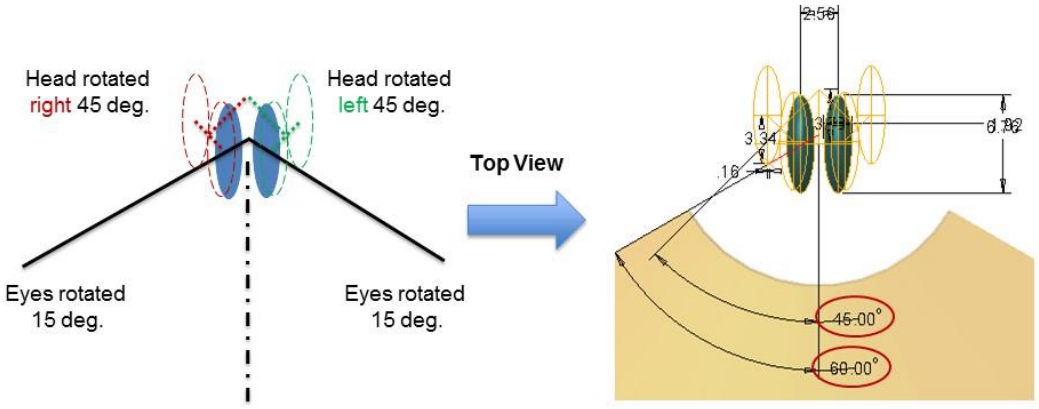




Intent | CAD Implementation

371

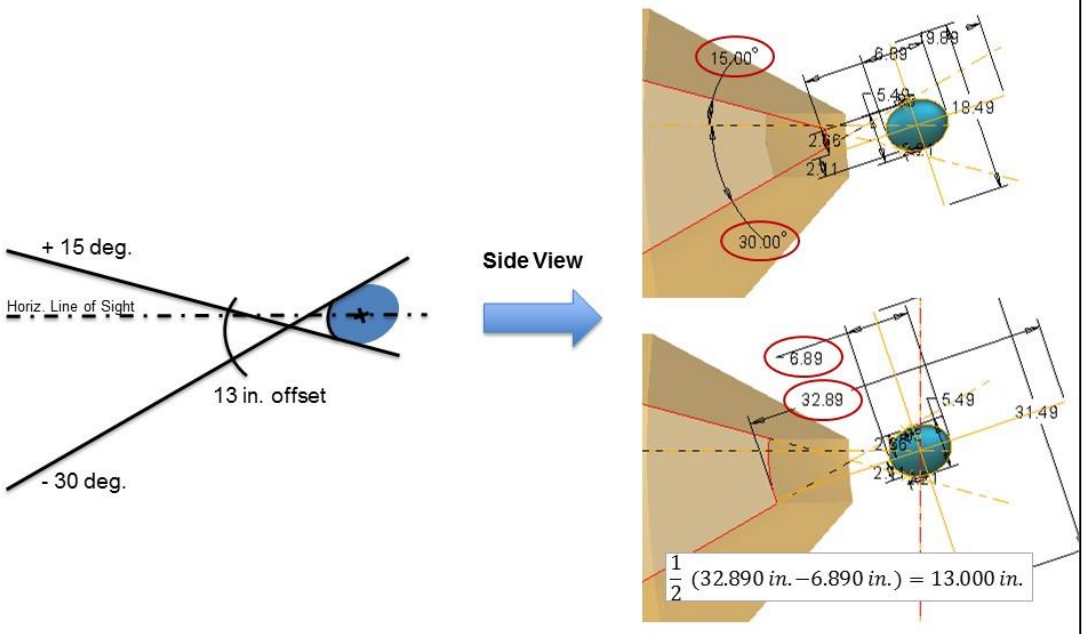
Test #10: Secondary Vision Zone



Intent CAD Implementation

372

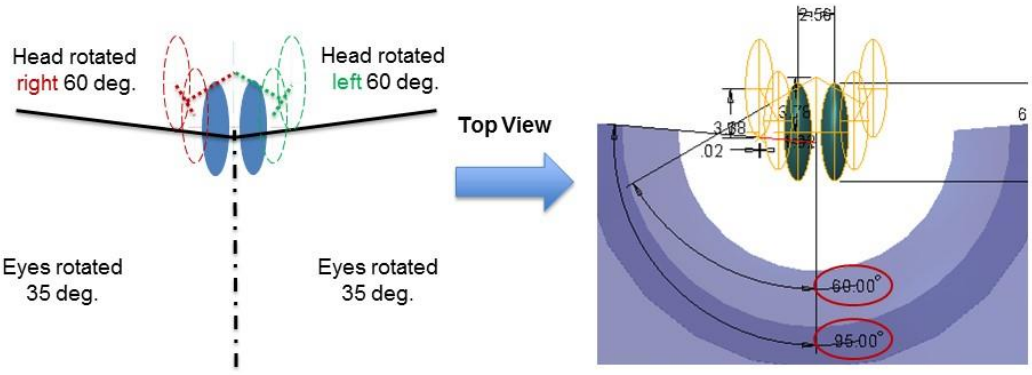
Test #10: Secondary Vision Zone (cont.)



Intent CAD Implementation

373

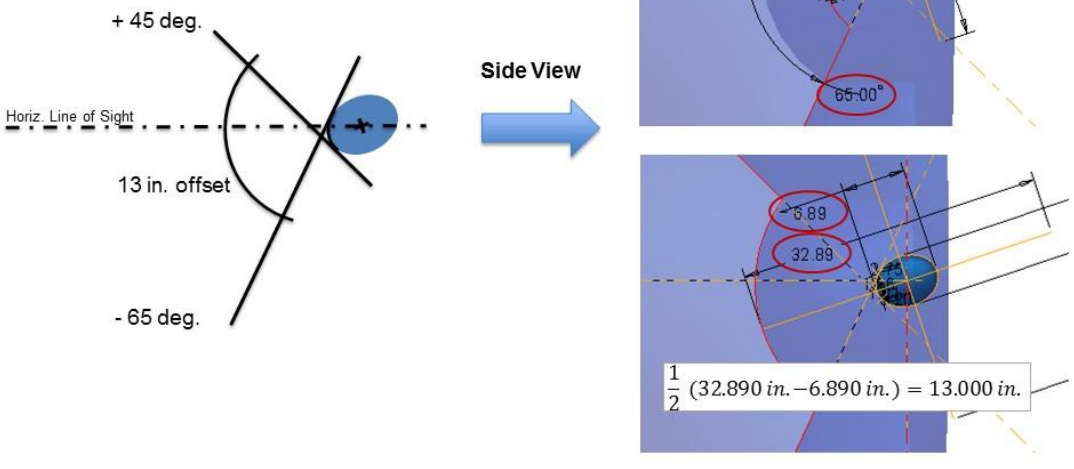
Test #10: Tertiary Vision Zone



Intent **CAD Implementation**

374

Test #10: Tertiary Vision Zone (cont.)



Intent **CAD Implementation**

375

Test #10: Vary Gender Mix, Ensemble, and Provide Hydration Pack Relief

Target Accommodation	Fraction Male	Ensemble	Steering Wheel Point (SWP) (measured wrt AHP)		Hydration Pack Relief Availability	HARP Measurement Tool
			X (in.) (L11, fore-aft)	Z (in.) (H17, vertical)		
90%	50%	ENC	13.3	29.0	Yes	SAE J826

Boundary Manikin Posture and Position

TARDEC CAD Model

376

Test #10: Numerical Results, Manikin Positioning

Small Overall Female						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM1_HIP_X	23.660	in	23.660	in	0.000	in
POSTURE_DHM1_HIP_Z	15.879	in	15.879	in	0.000	in
POSTURE_DHM1_EYE_X	24.940	in	24.940	in	0.000	in
POSTURE_DHM1_EYE_Z	38.171	in	38.171	in	0.000	in
Small Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM2_HIP_X	25.782	in	25.782	in	0.000	in
POSTURE_DHM2_HIP_Z	15.989	in	15.989	in	0.000	in
POSTURE_DHM2_EYE_X	26.191	in	26.191	in	0.000	in
POSTURE_DHM2_EYE_Z	39.938	in	39.938	in	0.000	in
Average Size Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM3_HIP_X	27.977	in	27.977	in	0.000	in
POSTURE_DHM3_HIP_Z	15.988	in	15.988	in	0.000	in
POSTURE_DHM3_EYE_X	27.599	in	27.599	in	0.000	in
POSTURE_DHM3_EYE_Z	42.162	in	42.162	in	0.000	in
Widest Shoulders Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM4_HIP_X	28.985	in	28.986	in	0.000	in
POSTURE_DHM4_HIP_Z	15.977	in	15.977	in	0.000	in
POSTURE_DHM4_EYE_X	28.255	in	28.256	in	0.000	in
POSTURE_DHM4_EYE_Z	43.440	in	43.440	in	0.000	in
Longest Torso Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM5_HIP_X	28.229	in	28.229	in	0.000	in
POSTURE_DHM5_HIP_Z	15.971	in	15.971	in	0.000	in
POSTURE_DHM5_EYE_X	27.765	in	27.765	in	0.000	in
POSTURE_DHM5_EYE_Z	44.441	in	44.441	in	0.000	in
Longest Legs Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM6_HIP_X	30.501	in	30.502	in	0.000	in
POSTURE_DHM6_HIP_Z	16.042	in	16.042	in	0.000	in
POSTURE_DHM6_EYE_X	29.176	in	29.176	in	0.000	in
POSTURE_DHM6_EYE_Z	42.661	in	42.661	in	0.000	in
Large Overall Male						
	UMTRI Value		TARDEC Value		Difference	
POSTURE_DHM7_HIP_X	30.327	in	30.327	in	0.000	in
POSTURE_DHM7_HIP_Z	16.139	in	16.139	in	0.000	in
POSTURE_DHM7_EYE_X	28.952	in	28.952	in	0.000	in
POSTURE_DHM7_EYE_Z	44.400	in	44.400	in	0.000	in

TARDEC CAD values to agree with UMTRI spreadsheet values within
±0.100 inches
±0.100 degrees

Largest Observed Differences:
0.000 inches

Values in agreement

377

Test #10: Small Overall Female

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	601.0	601.0	618.6	→	23.660	in
Hip re AHP Z	403.3	403.3	403.3	→	15.879	in
Eye re AHP X	669.5	633.5	630.5	→	24.940	in
Eye re AHP Z	969.6	969.6	969.6	→	38.171	in

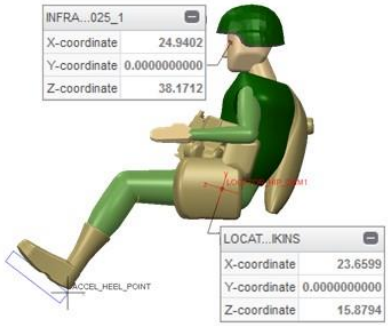
TARDEC CAD Model Calculations

POSTURE_DHM1_HIP_X	23.660	in
POSTURE_DHM1_HIP_Z	15.879	in
POSTURE_DHM1_EYE_X	24.940	in
POSTURE_DHM1_EYE_Z	38.171	in

*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Geometry



Side View

Front View

Test #10: Small Overall Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	654.9	654.9	672.5	→	25.782	in
Hip re AHP Z	406.1	406.1	406.1	→	15.989	in
Eye re AHP X	701.2	665.2	662.2	→	26.191	in
Eye re AHP Z	1014.4	1014.4	1014.4	→	39.938	in

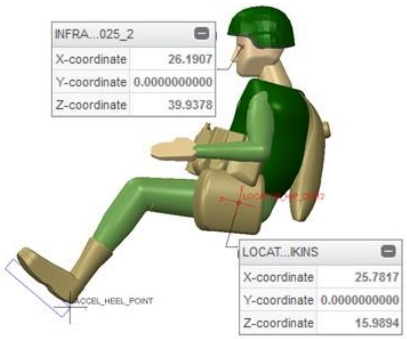
TARDEC CAD Model Calculations

POSTURE_DHM2_HIP_X	25.782	in
POSTURE_DHM2_HIP_Z	15.989	in
POSTURE_DHM2_EYE_X	26.191	in
POSTURE_DHM2_EYE_Z	39.938	in

*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Geometry



Side View

Front View

Test #10: Average Size Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	710.6	710.6	728.2	→	27.977	in
Hip re AHP Z	406.1	406.1	406.1	→	15.988	in
Eye re AHP X	737.0	701.0	698.0	→	27.599	in
Eye re AHP Z	1070.9	1070.9	1070.9	→	42.162	in

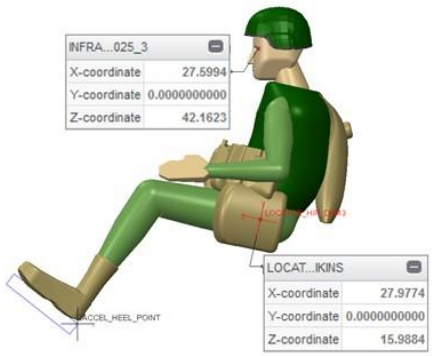
*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Calculations

POSTURE_DHM3_HIP_X	27.977	in
POSTURE_DHM3_HIP_Z	15.988	in
POSTURE_DHM3_EYE_X	27.599	in
POSTURE_DHM3_EYE_Z	42.162	in

TARDEC CAD Model Geometry



Side View

Front View

380

Test #10: Widest Shoulders Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	736.2	736.2	753.8	→	28.985	in
Hip re AHP Z	405.8	405.8	405.8	→	15.977	in
Eye re AHP X	753.7	717.7	714.7	→	28.255	in
Eye re AHP Z	1103.4	1103.4	1103.4	→	43.440	in

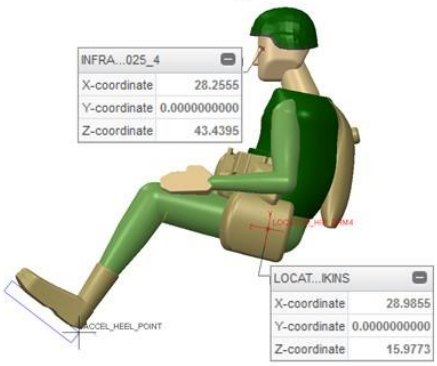
*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Calculations

POSTURE_DHM4_HIP_X	28.986	in
POSTURE_DHM4_HIP_Z	15.977	in
POSTURE_DHM4_EYE_X	28.256	in
POSTURE_DHM4_EYE_Z	43.440	in

TARDEC CAD Model Geometry



Side View

Front View

381

Test #10: Longest Torso Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	717.0	717.0	734.6	→	28.229	in
Hip re AHP Z	405.7	405.7	405.7	→	15.971	in
Eye re AHP X	741.2	705.2	702.2	→	27.765	in
Eye re AHP Z	1128.8	1128.8	1128.8	→	44.441	in

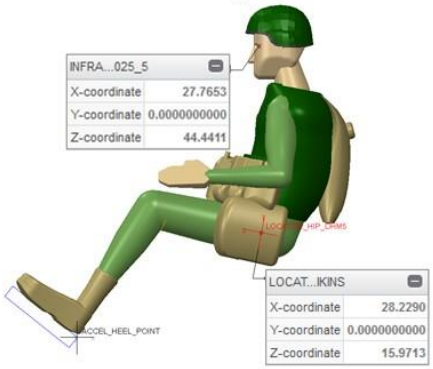
TARDEC CAD Model Calculations

POSTURE_DHM5_HIP_X	28.229	in
POSTURE_DHM5_HIP_Z	15.971	in
POSTURE_DHM5_EYE_X	27.765	in
POSTURE_DHM5_EYE_Z	44.441	in

*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Geometry



Side View

Front View

382

Test #10: Longest Legs Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	774.7	774.7	792.3	→	30.501	in
Hip re AHP Z	407.5	407.5	407.5	→	16.042	in
Eye re AHP X	777.1	741.1	738.1	→	29.176	in
Eye re AHP Z	1083.6	1083.6	1083.6	→	42.661	in

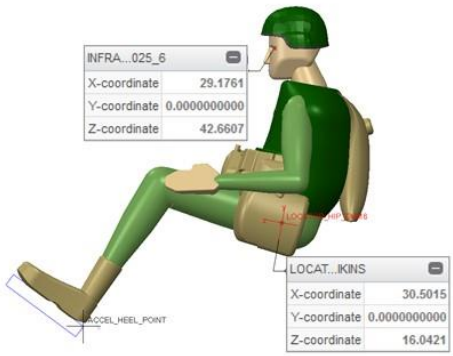
TARDEC CAD Model Calculations

POSTURE_DHM6_HIP_X	30.502	in
POSTURE_DHM6_HIP_Z	16.042	in
POSTURE_DHM6_EYE_X	29.176	in
POSTURE_DHM6_EYE_Z	42.661	in

*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Geometry



Side View

Front View

383

Test #10: Large Overall Male

UMTRI Spreadsheet Calculations*

	ACU	PPE **	ENC			
Hip re AHP X	770.3	770.3	787.9	→	30.327	in
Hip re AHP Z	409.9	409.9	409.9	→	16.139	in
Eye re AHP X	771.4	735.4	732.4	→	28.952	in
Eye re AHP Z	1127.8	1127.8	1127.8	→	44.400	in

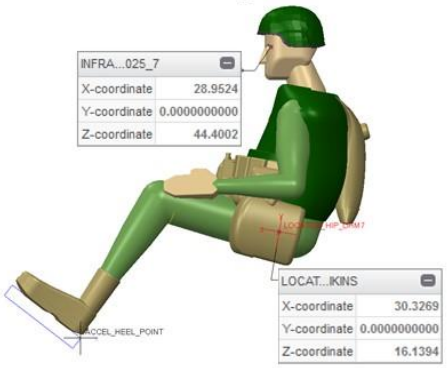
*Relevant values (highlighted) have been converted from millimeters to inches

**ENC ensemble combined with Hydration Pack Relief results in PPE positioning

TARDEC CAD Model Calculations

POSTURE_DHM7_HIP_X	30.327	in
POSTURE_DHM7_HIP_Z	16.139	in
POSTURE_DHM7_EYE_X	28.952	in
POSTURE_DHM7_EYE_Z	44.400	in

TARDEC CAD Model Geometry



Side View

Front View

384